CENTRE OF ADVANCED FACULTY TRAINING IN PLANT PATHOLOGY

(Indian Council of Agricultural Research, New Delhi)

Proceedings of the 26th Training

on

"DISEASES AND MANAGEMENT OF CROPS UNDER PROTECTED CULTIVATION"

September 04-24, 2012

Dr. K.S. Dubey, Director, CAFT

Dr. R.P. Singh, Course Coordinator

G.B. Pant University of Agriculture and Technology

Pantnagar- 263 145 (Uttarakhand)

PREFACE

Modern technology has given the farmers some powerful management tools for production. Generally, value added crops are grown under protected cultivation. Most of them are labour intensive and energy demanding. Green house production, therefore, normally requires a high level technology to obtain adequate economic returns on investments. Quality is a high priority for green house crops, requiring much care in pest and disease management, not only to secure yields but also to obtain a high cosmetic standard. Although technological changes are ultimately intended to reduce production costs and maximize profits, precise environmental and nutritional control push plants to new limits of growth and productivity. This can generate chronic stress conditions, which are difficult to measure, but apparently conducive to diseases and pests. Historically, not enough attention has been paid to exploiting and amending production technology for the control of diseases and pests. This makes the control of pests and diseases in protected crops even more challenging, with many important problems being unresolved and new ones arising as the industry undergoes more changes in production system.

In view of above, the 21 day training under Center of Advanced Faculty Training in Plant Pathology was designed to give an updated information/knowledge on "Diseases and Management of Crops under Protected Cultivation" to the participants, so that they can deal with the opportunity and applicability of emerging technologies for enhancing the agricultural productivity. Excellent response was received from all over India for participation in this training. Twenty two participants representing ten states, who actively participated in the programme, were exposed to the recent advances made towards various aspect of protected cultivation through series of lectures, practicals and field visits. We are grateful to the ICAR for sponsoring this 26th advanced training programme in series, and 5th under the banner of the newly created Centre of Advanced Faculty Training in Plant Pathology at Pantnagar. We are highly grateful to Shri. Subhash Kumar, Vice-Chancellor for his constant support, guidance and encouragement in making the training a great success. We are highly obliged to Dr. J. Kumar, Dean Agriculture for his keen interest, unending support and guidance received during the course of the training programme. We like to put on record the help and guidance received from All the Deans and Directors in the successful conduct of training programme. We sincerely acknowledge the services of our guest speakers Dr. Suresh Pandey, ICRISAT; Dr. J.C. Bhatt, Director, VPKAS, Almora; Dr. U.S. Singh, Sought-East Asia Coordinator, IRRI, New Delhi; Dr. Naved Sabir, NCIPM, New Delhi; Dr. S.K. Dwivedi, DRDO, New Delhi; Dr. V.K. Baranwal, Dr. Dinesh Singh, IARI; Dr. Narayan Chawda VNR, Seeds, Raipur, Chhatisgarh and Shri. Ravindra Mohan Sharma, Progressive Farmer, Nainital. We would like to place on record the help and logistic support received from Dr. M.P. Singh, Officer In-charge, ZRS/KVK, Lohaghat and his team of scientists for delivering lectures during exposure visit of participants. Several scientists from various departments such as Irrigation and Drainage Engineering; Biological Sciences; Plant Physiology; Agricultural Chemicals; Veterinary Anatomy; Horticulture; Vegetable Science; KNSCCF 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. We sincerely thank for very useful suggestions and guidance received from Dr. Alok Kalra, Head, Division of Microbial Technology, CIMAP, Lucknow for improvements in the conduct of training.

Dr. R.P. Singh
Course Coordinator

Dr. K.S. Dubey
Director, CAFT

Pantnagar
September 24, 2012

CONTENTS

REMARKS

by

Dr. K.S. Dubey
Director CAFT
Prof. & Head, Plant Pathology, College of Agriculture
G.B. Pant University of Agriculture & Technology, Pantnagar- 263 145

on

September 04, 2012

==========

Good Good morning and welcome to the Inaugural Session of the 26th Centre of Advanced Faculty Training on "Diseases and management of crops under protected cultivation".

Hon'ble Chief guest Dr. J.P. Pandey, Registrar; Dr. J.P. Singh, Director Experiment Station and Dr. S.C. Saxena, honorary professor, Dr. R.P. Singh, Course Coordinator of this training, Deans and Directors, Head of Departments, Senior faculty members, Colleagues, Staff members, the trainees from different universities, Students, Press & Media, Ladies & Gentle men.

At the outset, on behalf of faculty of Plant Pathology and on my own behalf and Dean, College of Agriculture, it is a pleasure in welcoming honorable Vice-Chancellor, who is known for his immense energy, strong integrity and commitment. Since, you have consented to grace this occasion despite of your very hectic schedule of work, we all are very grateful to you, Sir.

It is a pleasure in welcoming Dr. J.P. Singh, the Director of Research who has been very successfully coordinating and leading a very diverse research programme in the university. We all, members of Plant Pathology faculty welcome you.

I would also like to welcome Dr. S.C. Saxena, the senior most person in the College and a honorary professor in the Department of Plant Pathology. Dr. Saxena is the First Generation Staff in the Department as well as the College and is an appropriate interface to the younger generations coming to the Department.

I would also like to welcome my colleague Dr. R.P. Singh, the Course Coordinator of this CAFT training.

I welcome all the Deans and Directors who are present here in the hall. They have spared their valuable time to grace this occasion.

The Heads and faculty members of various departments have also responded to our request and are present in the hall. I welcome all of you to the function.

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 and others who are present in the hall and made the necessary arrangements for this inaugural session.

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 too and history of sound education, research and extension in Plant Pathology. Dr. Y.L. Nene was the first Head of the Department of Plant Pathology. Under his capable leadership, the department expanded to include many dedicated and extraordinary faculty members including, Dr. R.S. Singh and Dr. 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 08 professors, one senior professor as Emeritus Scientist and one as honorary professor, one honourary professor from INRA, France, 06 Associate Professors and 05 Assistant Professors with 14 technical and 08 supporting staffs. The entire staff upholds the Department's commitment to education, basic and applied research and extension.

The Department has a well-knit under graduate (U.G.) and post graduate (P.G.) programme with updated and modern course curricula. It offers 06 U.G. and 36 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 in areas of expertise and interests present in the Department, leads to diversity in thesis titles. So far about 335 M.Sc. and 195 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 as well as 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 Maize, Oilseeds, Potato, 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 while addressing current issues in Plant Pathology have won over 50 national and international awards. Individual staff members within 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 60 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 biocontrol and has given a number of technologies for both plains and hills. The biocontrol lab in the Department has been recognized as the referral lab by DBT. In the recent past, Government of India has declared the Biocontrol 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 with the major mandate to train scientific faculty from all over the country in important and innovative areas of Plant Pathology. So far 25 trainings have been conducted wherein 512 scientists from 25 states have participated.

The topic of the present training under CAFT is 'Diseases and management of crops under protected cultivation'. We all know that modern technology has given the farmers some powerful management tools for production. Generally, value added crops are grown under protected cultivation. Most of them are labour intensive and energy demanding. Green house production, therefore, normally requires a high level technology to obtain adequate economic returns on investments. Quality is a high priority for green house crops, requiring much care in pest and disease management, not only to secure yields but also to obtain a high cosmetic standard. Although technological changes are ultimately intended to reduce production costs and maximize profits, precise environmental and nutritional control push plants to new limits of growth and productivity. This can generate chronic stress conditions, which are difficult to measure, but apparently conducive to diseases and pests. Historically, not enough attention has been paid to exploiting and amending production technology for the control of diseases and pests. This makes the control of pests and diseases in protected crops even more challenging, with many important problems being unresolved and new ones arising as the industry undergoes more changes in production system.

In view of this, the present training programme is designed to give an updated information/knowledge on this very important subject not often available, to the participants, so that they can deal with the opportunity and applicability of emerging technologies for enhancing production and productivity under protected cultivation.

In last, I would like to extend my appreciations and special gratitude to the Faculty of Plant Pathology for their endorsement of the topic for the present CAFT training.

Finally, I would like to thank our Vice-Chancellor for allowing us to hold this training.

With these words I welcome you all and assure a fruitful and comfortable stay to the participants of this 26th training programme of CAFT in Plant Pathology.

Thank you very much!

* * * * * * * * *

INAUGURAL ADDRESS

by

Dr. J.P. Pandey
Registrar
G.B. Pant University of Agriculture & Technology, Pantnagar- 263 145
on
September 04, 2012

==========

Dean, Directors, faculty members, organizer of this summer school, participants from different parts of the country, media representatives and ladies and gentleman!

I am sure 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 more then 36 national/international awards from different recognized bodies like FAO, ICAR, Indian Phytopathological Society, Society of Mycology and Plant Pathology, Indian Society of Oilseeds Research and many others. On this particular occasion, I would like to make a mention of two giant plant pathologists, Dr. Y.L. Nene and Dr. R.S. Singh, who gave inspiring leadership to the Department of Plant Pathology during early 1960s soon after the establishment for the University on November 17, 1960. The first discovery goes to Dr. Nene by doing the discovery of *Khaira* disease 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 fulfilled. It was the single most important and simple factor in 1967 that earned a name for the university and the department by way of winning the FAO award.

Second eminent scientist Dr. R.S. Singh worked out basic mechanisms for obtaining the disease control of soil-borne plant diseases through soil organic amendments which is now becoming a reality and way of organic farming still existing after green revolution as ecologically sustainable agriculture farming system.. His books are considered to be the milestones for being handy text books both for under graduate and post graduate students & Teachers in Plant Pathology as well as extension workers and farmers. This department has to its credits considerable number of research publications and several books have been published by most reputed national and international publishers.

The Faculty of Plant Pathology at Pantnagar recognized the need for attention to role of protected cultivation, particularly the disease management, proves the importance of the subject for which the participants have come to study and participate in the

discussions. No doubt the course is very timely and will deal with a field of study which is relatively new to India and largely been neglected in comparison to other disciplines.

Green house technology is more than 200 hundred years old but it was introduced in India during 1985,s. Protected cultivation technology in our country went through a slow pace of expansion in the last 25 years. It is in its infancy state, the area under green house cultivation is reported to be about 2000 hectares in India. It can be safely stated that there exist a vast scope for expansion of green house technology in India.

The incidence of pest problems under protected conditions is higher than those in the open. The green house climate is ideal for the development of plant diseases. Due to high value of crops under such conditions, an economic threshold level of most insects and disease problem are lower and requires more monitoring and care. The pest management option under protected cultivation is often different than those recommended for the open field conditions. This necessitates human resource development with comprehensive knowledge on this new emerging area.

In relation to this particular training course some innovative eco-friendly measures i.e. greater use of cultural and biological practices and organic crop production need to be emphasized because the same crops are grown under poly houses repeatedly and more prone to the soil-borne plant pathogens and these practices are not only effective in managing soil pests but also contribution to the maintenance of soil health and soil fertility. This is especially important in the present context because high value crops are grown under poly houses and we need high quality produce, while presently we are highly dependent on chemical pesticides to control pests and diseases, which poses serious health threats due to toxic residues in food stuff. Today we realize that the use of chemical pesticides will become increasingly restricted because of concerns for the environment and health as well as increased cost of developing new pesticides to overcome resistance, developed by plant pathogens and insect pests and the restricted availability of some bio-control agents for economic and technical reasons in many developing countries particularly in India.

I formally inaugurate the event and congratulate organizing committee for designing and organizing such valuable course. I also wish the smooth conduct of this course.

Thank you

* * * * *

DEPARTMENT OF PLANT PATHOLOGY

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

Courses:

06 UG courses

37 PG courses

Staff position:

08 Professor

02 Honorary Professor

01 Guest Faculty

01 Emeritus Scientist

06 Associate Professor

05 Assistant Professor

14 Technical staff

08 Supporting staff

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 08 professors, 02 Honorary Professor, 01 Guest Faculty, 01 Emeritus Scientist, 06 Associate Professors and 05 Assistant Professor with 14 technical staff and 08 supporting staffs.

Sl. No.	Name of Faculty members	Designation	Area of specialization
1	Dr. K.S. Dubey	Professor & Head	Soybean diseases
2	Dr. J. Kumar	Professor & Dean Agriculture	Plant disease management on small farm, IPM, Biological control, Pathogen population biology.
3	Dr. K.P. Singh	Emeritus Scientist	Wheat Pathology
4	Dr. H.S. Tripathi	Guest Faculty	Pulse Pathology & Phytovirology

5	Dr. S.C. Saxena	Honorary Professor	Maize Pathology
6	Dr. Sergey Savary	Honorary Professor	Epidemiology
7	Dr. R.P. Awasthi	Professor	Oilseed crop diseases
8	Dr. (Mrs.) Karuna Vishunavat	Professor & Director Placement and Counselling	Seed Pathology
9	Dr. V.S. Pundhir	Professor	Potato Pathology & Epidemiology of Crop Disease
10	Dr. Pradeep Kumar	Professor	Maize Pathology & Fruit Pathology
11	Dr. R.K. Sahu	Professor	Sugarcane Pathology
12	Dr. K.P. Singh	Professor	Epidemiology & Management of Pulse Diseases
13	Dr. Vishwanath	Associate Professor	Soybean Pathology & Rapeseed Mustard diseases
14	Dr. Yogendra Singh	Senior Research Officer	Sorghum diseases
15	Dr. R.P. Singh	Senior Research Officer	Microbial ecology, fungicides & Vegetable Pathology
16	Dr. K.P.S. Kushwaha	Senior Research Officer	Pulse Pathology, Mycology (Mushroom)
17	Dr. A.K. Tewari	Senior Research Officer	Oilseed crops diseases & Bio-control
18	Dr. Satya Kumar	Associate Professor	Nematology
19	Dr. L.B. Yadav	Assistant Professor	Mycology
20	Dr. (Mrs.) Roopali Sharma	Junior Research Officer	Biological control, IPM Technology
21	Dr. S.K. Mishra	Junior Research Officer	Mushroom Biotechnology and Mushroom Biology
22	Dr. (Mrs.) Deepshikha	Junior Research Officer	Wheat diseases
23	Dr. (Mrs.) Geeta Sharma	Junior Research Offcer	Mushroom Breeding, its Diseases & spawn production
24	Dr. (Mrs.) N. W. Zaidi	Subject Matter Specialist (on EOL)	Biological control of plant disease & IPM

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 37 postgraduate courses leading to M.Sc. (Ag.) and Ph.D. degrees in Plant Pathology. Since the inception of the department 335 M.Sc. (Ag.) and 195 Ph.D. students have been awarded degrees.

Under graduate courses:

Sl. No.	Course N0.	Course name	Credit
1.	APP-312	Introductory Plant Pathology	3(2-0-3)
2.	APP-314	Crop Diseases & their Management	2(1-0-3)
3.	APP-330	Diseases of Fruit and Vegetable Crops	2(1-0-3)
4	APP/APE-322	Integrated Pest & Disease Management	2(1-0-3)
5.	APP-381	Mushroom Cultivation	1(0-0-1x2)
6.	APP-382	Biological Control of Plant Pathogens	2(0-0-2x2)

Post graduate courses:

Sl. No.	Course N0.	Course name	Credit
1.	APP-401	Introductory Plant Pathology	3(2-0-1)
2.	APP-410	Diseases of Field Crops	3(2-0-1)
3.	APP-430	Diseases of Horticultural Crops	3(2-0-1)
4	APP-507	Disease of Field and Medicinal Plants	3(2-0-1)
5.	APP-508	Disease of Fruits, and Ornamental Crops	3(2-0-1)
6.	APP-509	Disease of Vegetable and Spice Crops	3(2-0-1)
7.	APP/ENT- 514	Insects Vector of Plant Viruses and other Pathogens	2(1-0-1)
8.	APP-515	Biological Control of Plant Diseases	3(2-0-1)
9.	APP-516	Integrated Disease Management	3(2-0-1)
10.	APP-517	Mushroom Production Technology	3(2-0-1)
11.	APP-519	Post Harvest Diseases	3(2-0-1)
12.	APP/ENT-520	Plant Quarantine	2(2-0-0)
13.	BBB-599	Mycology	3(2-0-1)
14.	APP-600	Master's Seminar	1(0-0-1)
15.	APP-601	Special Problem	1
16.	APP-602	Plant Virology	3(2-0-1)
17.	APP-603	Plant Bacteriology	3(2-0-1)
18.	APP-604	Principles of Plant Pathology	3(3-0-0)
19.	APP-606	Principles of Plant Disease Management	3(2-0-1)
20.	APP-607	Plant Biosecurity and Biosafety	2(2-0-0)
21.	APP-611	Chemicals in Plant Disease Management	3(2-0-1)
22.	BBB-615	Advanced Mycology	3(2-0-1)
23.	APP-616	Advanced Plant Virology	3(2-0-1)
24.	APP-617	Advanced Bacteriology	3(2-0-1)
25.	APP-618	Principles and Procedures of Certification	1(1-0-0)
26.	APP-622	Techniques in Phytonematology	1(0-0-1)
27.	APP-624	Cultural & Chemical Control of Plant Parasitic Nematodes	2(1-0-1)
28.	APP-630	Phytonematology	2(1-0-1)
29.	APP-690	Master's Thesis Research	20
30.	APP-704	Molecular Basis of Host Pathogen Interaction	3(2-0-1)
31.	APP-710	Seed Health Technology	3(2-0-1)
32.	APP-712	Ecology of Soilborne Plant Pathogens	3(2-0-1)
33.	APP-713	Disease Resistance in Plants	2(2-0-0)
34.	APP-718	Epidemiology and Forecasting of Plant Diseases	3(2-0-1)
35.	APP-788	Doctoral Seminar I	1(0-0-1)

36.	APP-789	Doctoral Seminar II	1(0-0-1)
37.	APP-790	Ph.D. Thesis Research	45

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 – (17) (B) English– (43)

- ***Plant Disease*** 8th Edition by R.S. Singh
- ***An Introduction to Principles of Plant Pathology*** 4th Edition by R.S. Singh
- ***Plant Pathogens: The Fungi*** by R.S. Singh
- ***Plant Pathogens: The Viruses & Viroids*** by R.S. Singh
- ***Plant Pathogens: The Prokaryotes*** by R.S. Singh
- ***Integrated Disease Management*** by R.S. Singh
- ***Diseases of Fruit Crops*** by R.S. Singh
- ***Fungicides in Plant Disease Control*** by P.N. Thapliyal and Y.L. Nene
- ***Diseases of Annual Edible Oilseed*** *Crops* Vol.-I by S.J. Kolte
- ***Diseases of Annual Edible Oilseed*** *Crops* Vol.-II by S.J. Kolte
- ***Diseases of Annual Edible Oilseed Crops*** Vol.-III by S.J. Kolte
- ***Diseases of Linseed & Fibre Flex*** by S.J. Kolte
- ***Castor Diseases & Crop Improvement*** by S.J. Kolte
- ***Plant Diseases of International Importance*** *Vol.I:* ***Diseases of Cereals & Pulses*** by U.S. Singh, A. N. Mukhopadhyay, J. Kumar, and H.S. Chaube
- ***Plant Diseases of International Importance*** *Vol.II:* ***Diseases of Vegetables & Oil Seed Crops*** by 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*** A. N. Mukhopadhyay, J. Kumar, H.S. Chaube & U.S. Singh
- ***Pathogenesis & Host Specificity in Plant Diseases*** *Vol.I:* ***Prokaryotes*** by U. S. Singh, Keisuke Kohmoto and R. P. Singh
- ***Pathogenesis & Host Specificity in Plant Diseases*** *Vol. II:* ***Eukaryotes*** by Keisuke Kohmoto, U.S. Singh and R. P. Singh
- ***Pathogenesis & Host Specificity in Plant Diseases*** *Vol. III:* ***Viruses & Viroids*** by R. P. Singh, U.S. Singh and Keisuke Kohmoto.

- ***Aromatic Rices*** by R.K. Singh, U.S. Singh and G. S. Khush
- ***A Treatise on the Scented Rices of India*** by R.K. Singh and U.S. Singh
- ***Scented Rices of Uttar Pradesh & Uttaranchal*** by R. K. Singh and U.S. Singh
- ***Plant Disease Management : Principles & practices*** by H.S. Chaube and U.S. Singh
- ***Molecular Methods in Plant Pathology*** by R. P. Singh and U.S. Singh
- ***Soil Fungicides*** *Vol.-I* by A.P. Sinha and Kishan Singh
- ***Soil Fungicides*** *Vol.-II* by A.P. Sinha and Kishan Singh
- ***Experimental & Conceptual Plant Pathology*** *Vol.I:* ***Techniques*** by R.S. Singh, U. S. Singh, W.M. Hess & D.J. Weber
- ***Experimental & Conceptual Plant Pathology*** *Vol. II:* ***Pathogenesis and Host Specificity*** by R.S. Singh, U. S. Singh, W.M. Hess & D.J. Weber
- ***Experimental & Conceptual Plant Pathology*** Vol.III: **Defense** by R.S. Singh, U. S. Singh, W.M. Hess & D.J. Weber
- ***Seed Pathology***, 2 volumes by V.K. Agarwal
- ***Phytopathological Techniques*** by K. Vishunavat and S.J. Kolte
- ***Crop Diseases & Their Management*** by H.S. Chaube & V.S. Pundhir
- ***Seed borne diseases of crops & their management*** *by V.K. Agrawal & Y.L. Nene*
- ***Plant Pathogens: the Nematodes*** *by R.S. Singh*
- ***Disease of vegetables crops*** *by R.S. Singh*
- ***Introductory Plant Pathology*** *by H.S. Chaube & Ram Ji Singh*
- ***Seed Health Testing: Principles and Protocols*** *by Karuna Vishunavat*
- ***Fundamentals of Seed Pathology*** *by Karuna Vishunavat*
- ***Mushroom Production Technology*** *by R.P. Singh & H.S. Chaube*
- ***The Elements of Plant Virology: Basic concepts and practical class exercises*** *by S.J. Kolte & A.K. Tewari*
- ***A text book of Comprehensive Plant Pathology*** *by Karuna Vishunavat and S.J. Kolte*
- ***Ecofriendly Innovative Approaches in Plant Disease Management*** *by V.K. Singh, Y. Singh and A. Singh (2012)*

Books in Hindi:

- **सब्जियों के रोग**– जी0 एस0 दूबे, अमेरिका सिंह (1976)
- **फसलों के रोग** –ए0एन0 मुखोपाध्याय, आर0 ए0 सिंह (1976)
- **फलों के रोग**– पी0 एन0 थपलियाल, एस0 पी0 एस0 बेनीवाल (1976)
- **पौधों के रोग** –आर0 एस0 सिंह (1976)
- **कवकनाशी एवं पादप रोग नियंत्रण**– वाई0 एल0 नैन (1976)
- **फसलों के रोगों की रोकथाम**– संगमलाल (1984)

- **मशरूम उत्पादन तकनीकी**– आर0 पी0 सिंह, अशोक चौधरी, प्रदीप कुमार (1997)
- **मिलेट के रोग**–ए0 पी0 सिन्हा एवं जे0 पी0 उपाध्याय (1997)
- **सब्जियों के रोग**– एस0 एन0 विश्वकर्मा, एच0 एस0 चौवे एवं ए0पी0 सिन्हा (2003)
- **फलों के रोग** – एस0 एन0 विश्वकर्मा (2006)
- **सब्जियों के रोगों की रोकथाम** – एस0 एन0 विश्वकर्मा (2000)
- **बीज रोग विज्ञान–** वी0 के0 अग्रवाल (1999)
- **मक्का के रोग–** संगम लाल (1993)
- **धान के रोग** – आर0 ए0 सिंह एवं जे0 सी0 भट्ट (1995)
- **फसल–सब्जी–फल रोग, पहचान एवं प्रबन्ध** – योगेन्द्र सिंह एवं अखिलेश सिंह
- **व्यवहारिक मशरूम उत्पादन –** के0पी0एस0 कुशवाहा, के0के0 मिश्रा
- **सब्जियों के प्रमुख रोग एवं उनका प्रबन्धन–**शोभनाथ विश्वकर्मा

Manuals:

- **Chemicals in Plant Disease Control** by Y.L. Nene, R.K. Tripathi, P.N. Thapliyal & S.C. Saxena (1974)
- **Management of Soil Borne Plant Diseases** by R.S. Singh (1980)
- **Biocontrol of Fungal Plant Disease** by A.N. Mukhopadhyay, H.S. Chaube, U.S. Singh & S.C. Saxena (1994)
- **Identification of Plant Diseases and their Control** by A. N. Tewari (2000)
- **Epidemiology in Plant Diseases** by V.S. Pundhir (2000)
- **Disease resistance in plants** by V.S. Pundhir (2001)
- **Seed Pathology: A Practical Manual** by K. Vishunavat (2002)
- **Laboratory Methods in Plant Pathology** by Pradeep Kumar, Y.P.S. Rathi, & H.S. Tripathi (2002)
- **Phytovirology: Laboratory Manual** by Y.P.S. Rathi, H.S. Tripathi & Pradeep Kumar (2002)
- **Diagnosis of Plant Diseases** by A.N. Tewari (2002)
- **Identification of Plant Disease** by A.N. Tewari (2003)
- **Introductory Plant Pathology** (UG) by Y.P.S. Rathi, P. Kumar, & H.S. Tripathi (2003)
- **Diagnosis of Plant Diseases: Laboratory Manual** by A.N. Tewari (2004)
- **Mushroom Cultivation: Laboratory Manual** by R.P. Singh (2004)
- **Crop Diseases and their Management** by H.S. Chaube, V.S. Pundhir & S.N. Vishwakarma (2004)

- **Laboratory Manual of Forest Pathology** by K. P.Singh, J. Kumar and P. Srinivas (2007)
- **Integrated Pest Management** by Ruchira Tiwari, S.C.Saxena and Akhilesh Singh (2008)

Technical Bulletins:

- **Ascochyta blight of chickpea** by H.S. Chaubey (1987)
- **Botrytis grey mold of chickpea: survival and management** by Y.P.S. Rathi and H.S. Tripathi (1993)
- **Studies on sterility mosaic of pegion pea (*Cajanus cajan* (L) Millsp.)** by Y.P.S. Rathi (1983)
- **Studies on Fusarium** by R.S. Singh (1975)
- **Epidemiology and management of karnal bunt disease of wheat** by Amerika Singh (1994)
- **Plant parasitic soil nematodes of India** by K. Sitaramaiah, R.S. Singh, K.P. Singh and R.A. Sikora (1971)
- **False smut of rice** by R.A. Singh (1984)
- **Disease controling potential of some fungicides in soil as affected by Physico-chemical biological factors (IV volumes)** by H.S. Chaube *et al.* (1993)
- **A Handbook on Scientific Writing** by Y.P. S. Rathi (1998)
- **Major Diseases of Soybean and their Management** by Pradeep Kumar and Y.P.S. Rathi (2005)
- **Disease Free Seed Production of Soybean** by K. Vishunavat (2002)
- **Indian Minimum Seed Certification Standards** by K. Vishunavat, K., R.S. Verma, P. K. Shrotria, S.N. Tiwari, and Omvati Verma (2003)
- **Studies on Epidemiology and Management of Rust of Field Pea** by H.S. Tripathi (2003)

Extension Bulletin

- **Crop Diseases: Farmers Question and our Answer-** H.S. Chaube
- **फसलों के रोग: किसानों के प्रश्न हमारे उत्तर–** एच0 एस0 चौबे
- **खरीफ फसलों की उन्नत खेती एवम् अन्य कृषि व्यवसाय**–के. पी. सिंह (2008)
- **रबी फसलों की उन्नत खेती एवम् अन्य कृषि व्यवसाय**–के. पी. सिंह (2008)
- **धान की खेती में एकीकृत नाशीजीव प्रबन्ध–** यू0 एस0 सिंह
- **मृदा सौरीकरण–** एच0 एस0 चौबे एवं एस0 एन0 विश्वकर्मा
- **सेब के मुख्य रोग कीट एवं उनका समेकित प्रबन्धन–** के0 पी0 सिंह एवं जे0 कुमार
- **सब्जियों में समेकित नाशीजीव प्रबन्धन–** जे0 कुमार

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.*

Lentinula edodes

- 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).

Calocybe indica

- A relay cropping schedule developed for Tarai region of 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 multilocational 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.

Ganoderma lucidum

- Developed / standardized technology for production of traditional

value added mushroom products viz. 'Sev', 'Warian', 'Papad' and 'Mathri'.

- Isolated a high value cater pillar mushroom *Cordyceps sinensis* from high altitudes of Uttaranchal and analysed for antioxidative properties.

Cordyceps sinensis

MAJOR ACHIEVEMENTS

- Twenty seven wheat lines, combining better agronomic characteristics and resistance to diseases including Karnal bunt have been identified (Shanghi-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 10^8cells/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 25^0 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 scleroita

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, l*ight to dark brown glumes by *Sarocladium oryzae and D. oryzae,* and light to dark brown spots by *D. Australiense*.
- 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 oyzae* 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 resistan against Phytophthora stem blight.
- Some resistant donors for mungbean yellow mosaic virus have been identified i.e. UPU-1,UPU-2,UPU-3, UG-370, PDU-104, NDU-88-8, UG-737, and UG-774. The varieties thus evolved include PU-19, PU- 30, and PU-35., Manikya, resistant lines/cultivars identified: ML-62, ML-65, Pant M-4, Pant M-5, ML-131, NDM 88-14, ML-682, PDM-27, ML- 15, ML-803, ML-682 and 11/ 395 and for Urdbean leaf crinkle virus, SHU 9504, -9513,-9515, -9516, -9520, -9522, -9528, KU 96-1, UG 737 and TPU-4.
- 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 inability, 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 gray 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^{0}C, the mean minimum temperature of 6-10^{0}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 with in 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 pathotyope 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 harizianum*, *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 carbednazim 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-7394, PK-7121, PK-7391 were resistant.
- 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 @ 1l/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 in the Department, ICAR in 1995 upgraded the department to the status of the **Centre of Advanced Studies in Plant Pathology (CAS)** and now has been upgraded to **Centre of Advanced Faculty Training (CAFT).** Major mandate of the CAFT is to train scientific faculty from all over the country in important and innovative areas of Plant Pathology. So far 25 trainings, with 512 participants from 25 states, have been held The CAS was awarded by the education division, ICAR on August 14, 1998 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. The progress report CAS/CAFT in Plant Pathology 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)
3. Ecology and ecofriendly management of soil-borne plant pathogens (Jan 12 – Feb. 02, 1998)
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)
6. Recent advances etiology and management of root-rot and wilt complexes (Nov. 26 – Dec. 16, 1998)
7. Integrated pest management with particular reference to plant diseases: concept, potential and application (Nov. 23 –Dec. 13, 2000)
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)
10. Plant diseases diagnosis: past, present and future (Feb. 13, - March 05, 2002)
11. Chemicals in plant protection: past, present and future (Jan. 28 – Feb. 17, 2003)
12. Eco-friendly management of plant diseases of national importance: present status and research and extension needs (Nov. 10-30, 2003)

13. Ecologically sustainable management of plant diseases: status and strategies (March 22-April 11, 2004)
14. Disease resistance in field and horticulture crops: key to sustainable agriculture (Dec. 10-30, 2004)
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)
24. Climate change, precision agriculture and innovative disease control strategies (March 23 to April 12, 2011)
25. Quality Management and Plant Protection Practices for enhanced competitiveness in agricultural export (November 12 to December 02, 2011)
26. Diseases and Management of Crops under Protected Cultivation (September 04-24, 2012).

Sl. No.	State	Total	Sl. No.	State	Total
1.	Andhra Pradesh	14	14.	Maharashtra	39
2.	Arunachal Pradesh	01	15.	Manipur	01
3.	Assam	13	16.	Meghalaya	01
4.	Bihar	24	17.	Nagaland	01
5.	Chattishgarh	08	18.	Orissa	13
6.	Gujarat	44	19.	Punjab	06
7.	Haryana	04	20.	Rajasthan	45
8.	Himanchal Pradesh	38	21.	Sikkim	01
9.	Jammu & Kashmir	32	22.	Tamil Nadu	15
10.	Jharkhand	05	23.	Uttar Pradesh	71
11.	Karnataka	23	24.	Uttarakhand	84
12.	Kerla	05	25.	West Bengal	18
13.	Madhya Pradesh	28	26.	--	--
Total = 534					

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

OLD GLASS HOUSE RENOVATED



New Screen House Constructed

Research Project (on going)

- Programme Mode Support in Agrobiotechnology Phase-II (DBT)
- Translational Research Centre on Biopesticides (DBT)
- All India Coordinated Research Project on Biological Control (ICAR)
- All India Coordinated Wheat and Barley Improvement Project (ICAR)
- All India Coordinated Rice Improvement Project (ICAR)
- Cereal Systems Initiative for South ASIA (CSISA) Objective 3 (IRRI)
- Chitosan/Copper-Nanoparticles and Biopesticides for Knowledge-Based Plant Protection

(DBT)

- Large Scale Demonstration of IPM Technology through KVKs in Network Mode (HTMM-I)
- All India Coordinated Chickpea Improvement Project (ICAR)
- All India Coordinated Pigeonpea Improvement Project (ICAR)
- All India Coordinated MullaRP Improvement Project (ICAR)
- All India Coordinated Soybean Improvement Project (ICAR)
- All India Coordinator Research Project on Rapeseed & Mustard (ICAR)
- All India Coordinated Research Project on Seed Technology Research (NSP) (ICAR)
- DUS Test Centre for Implementation of PVP-LEGISLATION for Forage Sorghum at Pantnagar (ICAR)
- All India Coordinated Potato Improvement Project (ICAR)
- Pest risk assessment of potato crop in Kumaon Region of Uttarakhand (HTMM-I)
- All India Coordinated Maize Improvement Project (ICAR)
- Demonstration of Bio-intensive Integrated Pest Module in Tomato (NHB)
- All India Coordinated Sugarcane Improvement Project (ICAR)
- All India Coordinated Sorghum Improvement Project (ICAR)
- All India Coordinated Mushroom Improvement Project (ICAR)
- Demonstration of Existing Mushroom Production Technologies (HTMM-I)

Total Budget Outlay – > 1000 lakhs

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

Publication:

1.	Books	-	60
2.	Research Bulletins	-	20
3.	Research Papers	-	>1200
4.	Conceptual / Review articles	-	>130
5.	Chapters contributed to book	-	>150
6.	Extension literature (Hindi – English)	-	over (200)
	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
- Uttaranchal Ratana 2
- Education Award 2004-05" for his book "फलों के रोग" by the Ministry of Human Resource Development, GOI 01

Professional Societies and our Share:

Indian Phytopathological Societies

Presidents – 3

Zonal Presidents – 3

Indian Society of Mycology & Plant Pathology –

Presidents – 3

Vice Presidents – 1

Indian 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

M.Sc.	335
PhD	195

Trainings organized	No.	Persons trained
Summer schools (ICAR)	5	136
Summer training (DBT)	1	24
International training (IRRI)	1	11 (8 countries)
Under CAS/CAFT	26	534
Mushroom Production Training	10	260
Under SGSY on Mushroom Production	60	1785
Under HTM on Mushroom	15	398
Under RKVY on IPM	76	4130
Under HTM on IPM	90	2292
Under Seed Technology Research	05	150

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

Production and Management of Roses under Green House

Santosh Kumar
Department of Horticulture, G.B.P.U.A.& T., Pantnagar-263 145 (UK)

Introduction

Rose is the Nature's beautiful creations, known as Queen of flowers. It is a leading cut flower grown commercially all over the world. It ranks first in global cut flower trade. This flower has a worldwide consumption of more than 40 billion. However, its cultivation demands special care and attention, so that the flower blooms to their maximum potential. Rose is cultivated for cut flower, oil extraction, rose water and flavouring agent, hips of some rose species are rich in vitamin C, petals are used for preparing *Gulkand* and *Pankhuri*.

Tremendous progress has been made in raising new varieties by crossbreeding and selection. New types have arisen, the season of blooming has been prolonged to such an extent that many modern varieties bloom intermittently in some instances continuously throughout the summer and autumn months. Previously commercial rose cultivation in India was mainly in open field conditions. However, with the advent of state-of-the-art greenhouse cultivation in early 90's, large scale cultivation of export quality cut flower in protected condition started, thereby totally altering production dynamics. Cut flower trade is world wide dominated by Hybrid Tea roses.

Classification

- **Hybrid Tea:** Most popular in modern days bearing large flowers originally developed by crossing Tea roses and Hybrid Perpetuals.
- **Hybrid Perpetuals:** They are the immediate forerunners of Hybrid Tea.
- **Floribunda:** They are also known as Hybrid Polyanthas and were developed in 1924 from a cross between Hybrid Tea rose and Polyantha.
- **Grandiflora:** Mainly obtained from cross between Hybrid Tea and Floribunda types of roses. This class of rose produces beautifully formed, Hybrid Tea like blooms in clusters.
- **Polyanthas:** They produce enormous clusters of small flowers which bloom for several months.
- **Climbers and Ramblers:** Climbers grows upward with the help of modified organs. Ramblers are climbers with large clusters of small, single or double flowers.
- **Miniatures:** The miniatures are popular baby roses with small leaves and flowers. They are hardy and ideal for growing in pots.

Varieties used for cut flower purpose:

Flower colour	Variety
Red	Jaguar, Gabrilla, Sasha, Grand Gala, First Red, Dallas, E.G. Hill, Happiness.
Pink	Kiss, Europe, Prophyta, Royal, Nobles, Pink, Aristocrat, Better Times.

Bicolour	Amour, Rodeo, Confetti, Ambience, Lionides, Yellow Gloria.
Orange	Indian Puma, Candid, Mercedes, Jazz, Orange Delight, President Herbert.
Yellow	Golden Time, Golden Gate, Frisco, Golden Rapture, Golden Sceptor.
Cream	Prestige, Vivaldi, Verselia, Florence.
Purple	Jakaranka, Souvenier.
White	Eskimo, Double White Killarney, White Pearl.

Temperature and humidity maintenance:

Requires good light throughout the year. Temperature range of 15°C to 28°C and 75% relative humidity is ideal for quality rose growing.

Soil

Sandy loam, deep and well drained soil rich in organic matter having pH 5.5 to 6.3.

Propagation

- **Cuttings:** Matured current season shoots are selected for cuttings. The cut ends are dipped in root inducing hormone and planted in beds.
- **Micro propagation:** High frequency clonal propagation from auxiliary buds and shoot tip culture produce large quantities of chosen variety in a short span of time.
- **Budding:** The most common and preferred method, done in February-March, dormant eyes on a scion of chosen variety are budded either by T or inverted T or I method of budding on a root stock, commercially used rootstock is *Rosa indica* var *odorata.*

Cultural operations

Pruning: Done during first week of October under north Indian conditions and in last week of June and again in last week of November under Bangalore conditions. However, in case of essential oil yielding varieties of *Rosa damascena*, pruning is done from last week of December to the beginning of January. The height of pruning varies from 30-45 cm from ground level.

Pinching: Part of terminal growing portion of stem is removed to promote auxiliary branching and to delay maturity of buds.

Wintering: In this operation, the root is exposed in first fortnight of October to provide rest to the plants for further quality flower production.

Stem bending: Five months after planting, the stems are bent out in such a manner that the angle between original and bent shoot is less than 90^{o}.

Manure and Fertilizers:

In addition to the basal dose of well decomposed FYM (50 t/ha), rose requires 200-400 kg of N, 150 kg/ha of each P and K/ha. Nitrogen dose may be split into two, once at the time of pruning and the second dose after 20 days of pruning. The basal dose of fertilizers may also be supplemented with foliar feeding, consisting of 2 parts urea, 1 part dihydrogen ammonium phosphate, 1 part potassium phosphate and 1 part potassium nitrate using 3 g of this mixture/l of

water after one week or 10 days till flowering.

Diseases:

Die-back: This is the most serious of the rose disease in India. Earlier reports suggest that this disease was caused by fungus *Diplodia rosarum* Fr.

As the term die-back implies, the disease causes the death of the plant from top downwards. The disease starts from the pruned surface of the twigs. Initially it may be observed to the extent to a few centimeters below the pruned end, but in the severe cases, the disease spreads further and kills the entire plant.

Soil drenching with 2 g/l bavistin, benomyl or demosan, has also been reported to control the disease. Spraying with 0.2% captan or 0.2% mancozeb or 0.2% copper oxychloride immediately after pruning and then twice at 10 days interval is also effective for controlling die back of rose

Black spot: This disease is caused by *Diplocarpon rosae* Wolf.

This disease is also called leaf blotch, leaf spot, blotch and star sooty mold. Characteristics black spot 2-12 mm in diameter develops on upper leaf surfaces. These leaf spots are circular or irregularly coalescent with characteristic feathery, radiate, fibrillose margins of sub-cuticular mycelial strands.

The infected leaves as they are observed should be clipped off and burnt. Preventive sprays of ferbam (0.1%) at fortnightly intervals, benlate or bayleton (0.1%) applied just before the appearance of the spots helps in managing the disease. Bavistin (0.1%) was found most effective fungicide against leaf spot caused by *Diplocarpon rosae*.

Powdery mildew: It is a major disease of the rose all over the world caused by *Sphaerotheca pannosa* var. *rosae* (Wallr) Lev.

The disease affects all the aerial parts of the plant, though the leaves are found to be affected more. The younger leaves get curled, exposing the lower surface and such leaves are likely to be purplish than the normal leaves raised blister like areas develop in these leaves, which becomes coated with the white powdery growth of the fungus.

Insect:

Mites: These are minute, polyphagous pests found in large colonies on the underside of the leaves covered with fine silky webs. Due to their feeding, white specks appear on the leaves and these specks coalesce and appear as white patches. Ultimately, affected leaves become mottled. Abamectin (0.5 ml/l) or difenthiuron (Polo) should be sprayed.

Aphids: Large, dark green or pink brown aphids *Macrosiphum rosae* feed on buds, shoots and leaves. Colonies may persist throughout the year but are most numerous and troublesome in late spring and early summer. Foliage of infested plants is fouled with sticky honeydew and sometimes with sooty molds and growth may be checked. Aphid populations tend to increase most rapidly on soft and sappy growths. Use of nitrogenous fertilizers should be restricted. Systemic insecticides

like dimethoate (0.15%) should be sprayed to control aphids.

Thrips: When thrips populations are high on Roses, flower buds may become deformed and fail to open. Petals may be covered with brown streaks and spots. Western flower thrips can also vector certain tospoviruses including impatiens necrotic spot virus and several strains of tomato spotted wilt virus. Systemic insecticides like dimethoate (0.15%) should be sprayed.

Physiological Disorders:

Blind shoots: Characterized by failure of buds to produce the flowers. It may be due to premature bud harvest and excessive water loss during handling or exposure to high temperature, low humidity, ethylene, high microbial growth and incorrect use of floral preservatives.

Bull head: Bull head is also a common physiological disorder in roses observed mainly in low temperature during night. It occurs due to an abnormal production of cytokinins and gibberellins.

Harvesting:

For distant markets, harvested at tight bud stage and for local markets, buds should be harvested at more advanced stage of opening.

Postharvest Management:

After harvesting, the flowers should be shifted to cold rooms. During cooling, the stems should be put in aluminium sulphate or citric acid (300 ppm) or bleach powder (50 ppm chlorine). The floor of cold room should be cleaned with bleach solution every week to keep away the pathogens.

Grading and Packaging:

After cooling, stems shifted to air-conditioned grading room. Healthy stems are sorted out in different grades according to the stem length, cultivar and condition of the flower. Bud size should be representative to the variety and the length of the neck should not be much. The graded stems are made into bundles of 20 each, tied loosely with rubber band and wrapped with 2 ply soft corrugated paper and again tied loosely with a rubber band to secure the buds in position. The bunches are packed in pre-cooled 5-ply teleboxes of fibreboard in such a way that flower heads face in opposite direction. The boxes are taken to the airport in the refrigerated vans to keep the flowers cool.

Yield:

Under protected conditions, gives a yield of 150 to 300 quality flower stems per m^2 per year.

Integrated Pest Management in Protected Cultivation-Problems & Perspectives

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

Integrated pest management (IPM) is a broad based approach that integrates a range of practices for economic control of pests. The Food and Agriculture Organization of the UN defines IPM as "the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

Protected Cultivation and the Role of Crop Protection

The purpose of growing crops under greenhouse conditions is to extend their cropping season and to protect them from adverse environmental conditions, such as extreme temperatures and precipitation, and from diseases and pests (Hanan *et al*., 1978). Greenhouse structures are essentially light scaffolding covered by sheet glass, fibreglass or plastic. Such materials have a range of energy-capturing characteristics, all designed to maximize light transmission and heat retention.Modern technology has given the grower some powerful management tools for production. Generally, added-value crops are grown under protection. Most of them are labour-intensive and energy-demanding during cold weather. Greenhouse production therefore, normally requires a high level of technology to obtain adequate economic returns on investments. Quality is a high priority for greenhouse crops, requiring much care in pest and disease management, not only to secure yields but also to obtain a high cosmetic standard. Although technological changes are ultimately intended to reduce production costs and maximize profits, precise environmental and nutritional control push plants to new limits of growth and productivity. This can generate chronic stress conditions, which are difficult to measure, but apparently conducive to some pests and diseases. Historically, not enough attention has been paid to exploiting and amending production technology for the control of pests and diseases. This makes the control of pests and diseases in protected crops even more challenging, with many important problems being unresolved and new ones arising as the industry undergoes more changes in production systems.

Structure	ha (× 1000) in geographical area				
	Asia	Mediterranean[1]	North/South America	North Europe	Total
Direct cover (floating types)	5.5	10.3	1.5[2]	27.0	44.3
Low tunnels (row-covers)	143.4	90.5	20.0[2]	3.3	257.2
High tunnels	-	27.6[1]	-	-	27.6
Plastic-houses	138.2	67.7	15.6	16.7	238.2
Glass-houses	3.0	7.9	4.0	25.8	40.7

Distribution of protected cultivation worldwide(Wittewerand Castilla, 1995)

Importance of Protected Crops for Plant Production

Greenhouses were initially built in areas with long, cold seasons to produce out-of season vegetables, flowers and ornamental plants. Northern Europe is the paradigm of pioneering areas of greenhouse cultivation. Greenhouses protect crops against cold, rain, hail and wind, providing plants with improved environmental conditions compared to the open field. In greenhouses, crops can be produced out-of-season year-round with yields and qualities higher than those produced in the open field. Greenhouses have also allowed the introduction of new crops, normally foreign to the region (Germing, 1985).

There are two basic types of greenhouse. The first type seeks maximum control in an environment to optimize productivity. In Europe, optimal conditions for year-round production are provided in the glasshouses of The Netherlands, Belgium, the UK and Scandinavia. The other type of greenhouse, which is very common throughout the Mediterranean area, provides minimal climatic control, enabling the plants grown inside to adapt to suboptimal conditions, survive and produce an economic yield (Enoch, 1986; Tognoni and Serra, 1989; Castilla, 1994).

Reuveni *et al,.* (1989) observed a reduction in the number of infection sites of *B. cinerea* on tomato and cucumber when a UV-absorbing material was added to polyethylene film to increase the ratio of blue light to transmitted UV light. Blue photo selective polyethylene sheets have been suggested for their ability to reduce grey mould on tomato (Reuveni and Raviv, 1992) and downy mildew on cucumber (Reuveni and Raviv, 1997). Green-pigmented polyethylene reduced the conidial load and grey mould in commercial tomato and cucumber greenhouses by 35–75%. *Sclerotinia sclerotiorum* on cucumber, *Fulvia fulva* (Cooke) Cif. (= *Cladosporium fulvum* Cooke) on tomato and cucumber powdery mildew were also reduced (Elad, 1997).

The influence of greenhouse structures and covers on greenhouse climatic regimes may have strong consequences for pests and their natural enemies, as they have for diseases. In high-tech greenhouses, regulation of temperature and water pressure deficit enables the creation of conditions less favorable to pathogens and, in some cases, more favorable to bio control agents. The use of heating to limit development of a number of pathogens is well known (Jarvis, 1992). The use of high root temperatures in winter grown tomatoes in rock wool offers a non-chemical method of controlling root rot caused by *Phytophthora cryptogea* Pethybr. & Lafferty. The high temperature was shown to enhance root growth while simultaneously suppressing inoculum potential and infection, and, consequently, reducing or preventing aerial symptoms (Kennedy and Pegg, 1990). Careful control of the temperature also proved important in the case of hydroponically grown spinach and lettuce, in which it prevented or reduced attack by both *Pythium dissotocum* Drechs. and *Pythium aphanidermatum* (Edson) Fitzp. (Bates and Stanghellini, 1984). Recently, attacks of *P. aphanidermatum* on nutrient film technique (NFT) grown lettuce in Italy were related to the high temperature (>29°C) of the nutrient solution. Root rot was inhibited by reducing the temperature below 24°C (Carrai, 1993).Productivity is manifold in greenhouses in

comparison to growing the vegetables in open field as shown in the table below:

Table: Performance of tomato varieties under polyhouse and open field conditions in NEH region (Barapani)

Varieties	Polyhouse yield (q/ha)	Open field yield (q/ha)	Varieties	Polyhouse yield (q/ha)	Open field yield (q/ha)
BT-117-5-3-1	342.00	115.00	selection-2	233.00	73.83
KT-10	283.60	117.40	selection-1	2000.98	84.03
BT-10	294.00	111.65	KT-15	211.60	51.65
Arka Alok	260.00	57.90	H-24	143.17	58.75
BT-12	302.40	101.00	Arka Abha	193.50	70.33

Status

Commercial greenhouses with climate-controlled devices are very few in the country. Solar Green houses comprising of glass and polyethylene houses are becoming increasingly popular both in temperate and tropical regions. In comparison to other countries, India has very little area under greenhouses as is evident from Table below:

Table: Approximate area (ha) under greenhouses

Country	Area	Country	Area
Japan	54000	Turkey	10000
China	48000	Holland	9600
Spain	25000	USA	4000
South Korea	21000	Israel	1500
Italy	18500	India	3000

Purpose of Glasshouse

1. The purpose of growing crops under greenhouse conditions is to extend their cropping season and to protect them from adverse environmental conditions, such as extreme temperatures and precipitation, and from diseases and pests
2. Greenhouse production normally requires a high level of technology to obtain adequate economic returns on investments

Problems in glasshouses

1. Normally value added crops are grown under protection most of them are laboure intensive and energy demanding during cold weather
2. Normally high level of technology to obtain adequate economic returns
3. Quality is a high priority for greenhouse crops, requiring much care in pest and disease management, not only to secure yields but cosmetic standard
4. Continues cropping is practiced ,without a fallow--- it leads to the build-up of soil- borne and foliar pathogens
5. This can generate chronic stress conditions ,which are conducive to some pests and diseases

Factors Favorable to Pest and Disease Development: Well-grown and productive crops are generally less susceptible to diseases, but in many cases compromises have to be made between optimum conditions for economic productivity and conditions for disease and pest prevention. Well-fertilized and irrigated crops are, however, often more sensitive to pests, like aphids, whiteflies and leafminers. High host plant densities and the resulting microclimate are favorable to disease spread. Air exchange with the outside is restricted, so water vapour transpired by the plants and evaporated from warm soil tends to accumulate, creating a low vapour pressure deficit (high humidity). Therefore, the environment is generally warm, humid and wind-free inside the greenhouse. Such an environment promotes the fast growth of most crops, but it is also ideal for the development of bacterial and fungal diseases (Baker and Linderman, 1979; Fletcher, 1984; Jarvis, 1992), of insects vectoring viruses and of herbivorous insects. For bacteria and many fungi (causal agents of rusts, downy mildews, anthracnose, grey mould, etc.) Greenhouses are designed to protect crops from many adverse conditions, but most pathogens and several pests are impossible to exclude. Windblown spores and aerosols containing bacteria enter doorways and ventilators; soilborne pathogens enter in windblown dust, and adhere to footwear and machinery. Aquatic fungi can be present in irrigation water; insects that enter the greenhouse can transmit viruses and can carry bacteria and fungi as well. Once inside a greenhouse, pathogens and pests are difficult to eradicate.

Problems in protected cultivation

Greenhouses are designed to protect crops from many adverse conditions, but most pathogens and several pests are impossible to exclude as:

1. Windblown spores and aerosols containing bacteria enter doorways and ventilators
2. Soil-borne pathogens enter in windblown dust, and adhere to footwear and machinery
3. Aquatic fungi can be present in irrigation water
4. Insects that enter the greenhouse can transmit viruses and can carry bacteria and fungi as well
5. Once inside a greenhouse, pathogens and pests are difficult to eradicate eg. leach

Factors Stimulating Sustainable Forms of Crop Protection in Protected Cultivation: Protected cultivation is an extremely high-input procedure to obtain food and other agricultural products per unit of land, although inputs are the lowest when related to the yield per area. Among the factors stimulating sustainable forms of crop protection are the following:

1. Consumer concern about chemical residues.
2. Pesticide-resistance in pests and pathogens.
3. Side-effects of chemical application are increasingly observed in old and new growing areas.
4. Efficacy: Some pests and diseases are difficult – sometimes impossible – to control if an integrated approach is not adopted.

Sometimes this can be achieved cheaply – in both economic and energetic terms – By means of correct crop and management practices. As mentioned before, the most damaging pests and many pathogens in greenhouses are polyphagous; although they are able to develop on many host plants, their negative effect on yield varies with host plant species and cultivar. The development of cultivars which are less susceptible to pests and diseases or that favour the activity of pest natural enemies is undoubtedly one of the most sustainable ways to control diseases in greenhouses and its potential for pests has been shown in a few but significant cases.

REFERENCE

- Baker, K.F. and Linderman, R.G. (1979) Unique features of the pathology of ornamental plants, *Annual Review Phytopathology* 17, 253–277.
- Bates, M.L. and Stanghellini, M.E. (1984) Root rot of hydroponically grown spinach caused by *Pythium aphanidermatum* and *P. dissotocum*, *Plant Disease* 68, 989–991.
- Carrai, C. (1993) Marciume radicale su lattuga allevata in impianti NFT, *Colture Protette* 22(6), 77–81.
- Castilla, N. (1994) Greenhouses in the Mediterranean area: Technological level and strategic management, *Acta Horticulturae* 361, 44–56.
- Enoch, H.Z. (1986) Climate and protected cultivation, *Acta Horticulturae* 176, 11–20.
- Fletcher, J.T. (1984) *Diseases of Greenhouse Plants,* Longman, London.
- Germing, G.H. (1985) Greenhouse design and cladding materials: A summarizing review, *Acta*
- Hanan, J.J., Holley, W.D. and Goldsberry, K.L. (1978) *Greenhouse Management*, Springer-Verlag, Berlin *Horticulturae* 170, 253–257.
- Jarvis, W.R. (1992) *Managing Diseases in Greenhouse Crops,* American Phytopathological Society Press, St Paul, Minn.
- Kennedy, R. and Pegg, G.F. (1990) *Phytophthora cryptogea* root rot of tomato in rock wool nutrient culture. III. Effect of root zone temperature on infection, sporulation and symptom development, *Annals of Applied Biology* 117, 537–551.
- Reuveni, R. and Raviv, M. (1992) The effect of spectrally-modified polyethylene films on the development of *Botrytis cinerea* in greenhouse grown tomato plants, *Biological Agriculture & Horticulture* 9, 77–86.
- Reuveni, R. and Raviv, M. (1997) Control of downy mildew in greenhouse-grown cucumbers using blue photoselective polyethylene sheets, *Plant Disease* 81, 999–1004.
- Reuveni, R., Raviv, M. and Bar, R. (1989) Sporulation of *Botrytis cinerea* as affected by photoselective sheets and filters, *Annals of Applied Biology* 115, 417–424.
- Tognoni, F. and Serra, G. (1989) The greenhouse in horticulture: The contribution of biological research, *Acta Horticulturae* 245, 46–52.
- Wittwer, S.H. and Castilla, N. (1995) Protected cultivation of horticultural crops worldwide,
- *HortTechnology* 5, 6–23.

Soil Solarization in Field and Plastic Houses for the Management of Soil Borne Diseases

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

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 anyone 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 innovative 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. Soil solarization is a non-chemical soil disinfestation method applied worldwide for the control of soil borne plant pathogens, weeds and nematodes.

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. 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. 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 farmers and can be applied in large areas manually and mechanically. 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 wide variety of pests is achieved.

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). Soil solarization applied singly or in combination with

biocontrol agents or reduced doses of soil fumigants/fungicides has shown a remarkable destructive effect on most soil borne plant pathogens.

Various terms like solar heating, plastic or polyethylene tarping, polyethylene or plastic mulching of soil have been used to describe this method. Since this method involves repeated daily heating at relatively mild temperatures, the term solar pasteurization has also been suggested.

Principles

Heat is used as a lethal agent for the control of plant pathogenic organisms through the use of transparent polyethylene soil mulches (tarps) for capturing solar energy. Polyethylene covering of soil induces green house effect and raises soil temperature. The following recommendations are made to bring about effective solar heating of soil:

- Transparent (clear) not black polyethylene should be used since it transmits most of the solar radiation that heats the soil. Black polyethylene, though it is greatly heated by itself, is less efficient in heating the soil than transparent sheet.
- Soil mulching should be carried out during the period of high temperatures and intense solar irradiation.
- Soil should be kept wet during mulching to increase thermal sensitivity of resting structures such as sclerotia, chlamydospores, etc. and to improve heat conduction.
- The thinnest possible polyethylene tarp (25-30 µm) is recommended, since it is both cheaper and more effective in heating, due to better radiation transmittance, than the thicker one. Polyethylene reduces heat convection and water evaporation from the soil to the atmosphere. As a result of the formation of water droplets on the inner surface of the polythene film, its transmissivity to long wave radiation is highly reduced, resulting in better heating due to an increase in its greenhouse effect. An ideal plastic mulch is that which is 100% transparent to solar radiation and completely opaque to long wave radiation. This ideal mulch can increase soil temp. by 6-8^{0}c over ordinary polyethylene.
- Since temperatures at the deeper soil layers are lower than at the upper ones, the mulching period should be sufficiently extended, usually 4 weeks or longer, in order to achieve pathogen control at all desired depths.

The solar heating method for disease control is similar, in principle, to that of artificial soil heating by steam or other means. There are, however, important biological and technological differences: (i) With soil solarization there is no need to transport the heat from its source to the field. (ii) Solar heating is carried out at relatively low temperatures as compared to artificial heating; thus its effects on living and nonliving components are likely to be less drastic. Negative side effects observed with soil steaming such as phytotoxicity due to release of manganese or other toxic products and a rapid soil reinfestation due to the creation of a biological vacuum have not been reported so far with solar heating.

Absorption of solar radiation in different soils varies according to the colour, moisture, and texture of the soil. In general, the soil has high thermal capacity and is a poor heat conductor thus resulting in a very slow heat penetration in soil. The energy is lost from the soil in the form of long wave radiation through conduction, convection, and water evaporation. The principles of solar heating in polyethylene mulched soil were demonstrated by Waggoner *et al*., 1960. If thermal processes occurring in mulched soil are considered, then soil temperatures at the desired depth can be predicted. Mahrer, 1979 developed a one dimensional numerical model for such predictions. As per this model in wet, polyethylene mulched soil, increased temperatures are due primarily to the elimination of heat loss by evaporation and heat convection during the day time and partially to the green house effect (preventing part of the long wave radiation from leaving the ground). By predicting the temperatures at any depth of the mulched soil, the model enables us to select the suitable climatic regions and the time of year most adequate for solarization of soil, providing data on the heat sensitivity of the pathogens and their population density at various depths are available. Relative importance of type of mulching material, soil type, moisture and climatic factors can also be evaluated. Analysis of the spatial soil temperature regimes in mulched soil showed that heating at the edges of the mulch is lower than at the center, and that a narrow mulch strip is less efficient in heating than a wider one (Mahrer and Katan, 1981).

Mechanisms

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.

Whenever microorganisms are subjected to moist heat, at temperatures exceeding the maximum for growth, their viability is reduced. The thermal death rate of a population of an organism depends on both the temperature level and exposure time, which are inversely related. At a given temperature and time of exposure, mortality rate is related to the inherent heat sensitivity of the organisms and to the prevailing environmental conditions. In general, populations of soil borne fungal pathogens are drastically reduced at temperatures of 40-50^{0}C, exposure time ranging from minutes to hours for the higher temperatures, and up to days for the lower temperatures. The response of the population to elevated temperatures depends on propagule type, age and on environmental factors like pH, presence of ions etc. Presence of moisture is a crucial factor since microorganisms are much more resistant to heat under dry conditions. The effect of water can be explained by the dependence of the heat stability of proteins on hydration. In the presence of water less energy is required to unfold the peptide chain of proteins, resulting in a decreased heat resistance. Heating dry soils is therefore not effective in pathogen control (Katan *et al.*, 1976).

Microbial processes, induced in the soil by solarization, may contribute to disease control, since the impact of any lethal agent in the soil extends 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 pathogen survival or disease development during or after solarization, through antibiosis, lysis, parasitism, or competition.

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., bacterial pathogens such as Agrobacteria and *Pseudomonas* and many species of nematodes in many crops both under field conditions and plastic houses (Katan *et al*., 1983; Abdul *et al*., 1995; Raoof and Rao,1997; Chellemi *et al*., 1994). The m,ethod has also been used to control many species of nematodes. Diseases caused by *Meloidogyne* spp., *Heterodera* spp. etc.have been successfully controlled by soil solarization (Rao and Krishnappa, 1995; Grinstein *et al*., 1995).

Polyhouse farming is an alternative emerging technique in agriculture which is becoming increasingly popular . It reduces dependency on rainfall and makes the optimum use of land and water resources. Polyhouse farming enables, raising off-season nurseries, maintenance and multiplication of self incompatible line for hybrid seed production, cultivation of flowers, vegetables

like tomato, chilli, capsicum, brinjal, cucumber, broccoli and exotic crops that can't be normally grown in Indian conditions. It also enables cultivation of off-season crops regular, thus fetching the farmer a higher price. Parameters such as moisture, soil nutrients and temperature in the polyhouse are controlled to ensure timely and abundant yields. Productivity is manifold in greenhouses in comparison to growing the vegetables in open field. Engineering advances have improved crop yields by controlling the environment in the polyhouses. The estimated area under green house cultivation in India is 2000 ha that includes 500 ha area under net house, shed house and 1500 ha under green house, which is mainly in Maharashtra, Uttarakhand, Karnataka, Jammu & Kashmir. The total area under polyhouse in Uttarakhand is 200 hactares.

Protected structures on one hand provide ambient growing conditions to the plant, on the other hand this condition is favourable to the plant pathogens also. Though protected farming has advantage that pathogen do not enter easily from outside but once a pathogen has introduced, it is very difficult to manage. Control of particularly soil borne plant pathogen under polyhouse is a challenge, as traditional practices like crop rotation, fallow, mixed cropping etc. usually cannot be applied. Solarization appears to be of major use in greenhouse culture. Many greenhouse and nursery crops worldwide now utilize solarization. The ability of greenhouse operators to close up greenhouses during the hot summer months allows higher solarization temperatures than achievable in treatment of open fields. Another application for which solarization may come into common use, particularly in developing countries, is for disinfestation of seedbeds, containerized planting media, and cold-frames. As with use in greenhouses, these are ideal niches for solarization, since individual areas to be treated are small, soil temperature can be greatly increased, the cost of application is low, the value of the plants produced is high, and the production of disease free planting stock is critical for producing healthy crops.

Weed Control

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. Weed control may be effected by direct killing of weed seeds by heat, indirect microbial killing of seeds weakened by sublethal heating, killing of seeds stimulated to germinate in the moistened solarized soil, and killing of germinating seeds whose dormancy is broken in the heated soil. Volatiles may also play a role in weed control (Horowitz, 1980; Rubin and Benzamin, 1981).

Increased growth response

Plant growth in solarized infested soil is enhanced as compared to untreated, infested soil as a result of pathogen control but solarization of soil which is apparently free of known pathogens often results in improved plant growth. This could be attributed to increased micro and macro nutrients in soil solution, elimination of minor or unknown pathogens, destruction of phytotoxic substances in the soil, release of growth regulator like substances, and stimulation of mycorrhiza,

PGPR, and other beneficial microorganisms. The effect of soil solarization on earthworms population has not received much attention but it is thought that they retreat to lower depths to escape the effect of soil heating. 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 (Broadbent *et al*, 1977; Katan, 1987; Chen *et al*., 1991; Singh, 2008).

Combining solarization with other methods

Despite the successes achieved with solarization when used singly this method may be usefully aided by combination with other methods of disinfestation. As soil solarization is dependent upon local climatic conditions, sometimes even during conducive periods of the year, local weather conditions will not permit an effective solarization treatment. Therefore, we must come up with integrated uses of solarization in order to increase the predictability of the treatment and thus make it more acceptable to growers. Combining solarization with pesticides, organic amendments, 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.

Low application rates of fungicides, fumigants or herbicides have been successfully combined with soil solarization to achieve better pest control (Hartz *et al*, 1993).Simultaneous application of chemicals and tarping the soil for solarization has been shown to increase the effectiveness of both the methods because of synergism (Ben –Yephet *et al.* 1988; Tjamos, 1984). Reduced doses of metham-sodium (12.5 or 25 ml/m^2) applied singly or in combination with soil solarization synergistically destroyed *V. dahliae* and *F. oxysporum* f.sp. *vasinfectum i*n a naturally infected cotton field. The synergism was attributed to the weakening effect induced by increased soil temperatures along with the toxicity of the chemical. The combination also reduced to one week the time needed to kill sclerotia of *Sclerotinia sclerotiorum* in the top 10 cm of soil in a lettuce field and reduced apothecia production. Carbendazim has shown slower degradation rates after solarization, possibly because of changes in the populations of soil microorganisms after solarization.

Solarization may also be combined with application of crop residues, green and farm yard manures. There is increasing evidence that these materials release volatile compounds in the soil that kill pests and help stimulate the growth of beneficial soil organisms (Deadman *et al*, 2006; Gamliel and Stapleton, 1993).

Soil solarization has also been successfully combined with biological control. The use of *Trichoderma harzianum* with solarization in fields infested with *Rhizoctonia solani* has been shown to improve disease control while delaying the buildup of inoculum (Chet *et al*, 1982). Greenberger *et al*, 1987 concluded that solarized soils are frequently more suppressive and less conducive to certain soil borne pathogens than non-solarized soils. An increase in population of green fluorescent pseudomonads along with an increase of *Penicillium* and *Aspergillus* spp. following

solarization has been demonstrated (Stapleton and DeVay, 1982).

Limitations

Solarization involves limitations, difficulties and possible negative effects.

- It is weather dependent and 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. The soil heating effect may be limited on cloudy days. Wind or air movement across the plastic sheet rapidly dissipates the trapped heat. Strong winds may also lift or tear the 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

Future Thrust

Economics: The economic profitability of disease control depends on the additional income obtained and the cost of application. The additional income obtained through solarization far exceeds with high-value crops but with other crops situation may not be the same. There are several possibilities for reducing the cost of mulching: (a) Used polyethylene may be as effective as the new, thus reducing the cost to nearly zero (b) Reusing the polyethylene, providing it is durable (c) If required during the growing season, durable sheets may be used for both solarization and mulch (d) The production of thinner polythene sheets (of an adequate strength) will reduce the amount needed per hectare.

Development in plastic technology: Developments in this field may provide improved and economical mulching materials with greater heating efficiency and increased durability. This may include 1) Biodegradable plastic that decomposes in the natural environment 2) Further development of polyethylene recycling processes 3) Developing economic, novel plastic or other materials more efficient than polythene in trapping solar energy, thus reducing our dependence on climate and making this available to cooler regions 4) Possibility of plastic material that can be sprayed on the soil, instead of polyethylene mulching, should be explored. At present, biodegradable plastic products available in the market are more expensive than traditional plastics. Their cost needs to be reduced to make them economical.

REFERENCES

- Abdel Rahim, M. F., Satour, M. M., Mickail, K.Y. and El Eraki, S. A. (1988). Effectiveness of soil solarization in furrow irrigated Egyptian soils. *Plant Dis.*. **72**: 143-146.
- Barbercheck, M.E.and von Broembsen, S.L (1986). Effect of soil solarization on plant parasitic nematodes and *Phytophthora cinnamomi* in South Africa.*Plant Dis*. **70**:945-950.
- Broadbent, P, Baker, KF, Franks, N and Holland, J. 1977. Effect of Bacillus spp. on increased growth of seedlings in steamed and in non treated soil. Phytopathology. 67: 1027-1034.

- Chellemi, D.O.., Olson, S.M. and Mitchell, D. J. (1994). Effect of soil solarization and fumigation on survival of soil borne pathogens of tomato in Northern Florida. *Plant Dis*. 78: 1167-1172.
- Chen, Y., Gamliel, A., Stapleton, J. J. and Aviad, T. (1991). Chemical, physical and microbial changes related to plant growth in disinfested soils. In: Soil Solarization. Katan, J. and De Vay, J. E. (eds.) CRC Press, Inc., Boca Raton, FL. pp. 103-129.
- Chet, I, Elad, Y, Kalfon, A, Hadar, Y and Katan, J. 1982. Integrated control of soilborne and bulbborne pathogens in iris. *Phytoparasitica*. 10:229.
- Deadman, M, Al Nasani, H and Al Sa'di, A. 2006. Solarization and Biofumigation reduce Pythium aphanidermatum induced damping off and enhance vegetative growth of green house cucumber in OMAN. *Journal of Plant Pathology*. 88: 335-337.
- Gamliel, A and Stapleton, J. 1993. Effect of chicken compost or ammonium phosphate and solarization on pathogen control, rhizosphere organisms, and lettuce growth. *Plant Disease*. 77:886-891.
- Grinstein, A., Kritzman, G., Hetzroni, A., Gamliel, A. Mor, M. and Katan, J. (1995). The border effect of soil solarization. *Crop Protect*. 14: 315-320.
- Hartz, T, DeVay, J and Elmore, C. 1993. Solarization is an effective soil disinfestations technique for strawberry production. Hort. Sci. 28(2): 104-106.
- Horowitz, M. 1980. Weed research in Israel. Weed Sci. 28: 457-460.
- Katan, J, G Katan, J, Greenberger, A, Alon, H and Grinstein, A. 1976. Solar heating by polyethylene mulching for the control of diseases caused by soil-borne pathogens. *Phytopathology*. 66: 683-688.
- Katan, J. (1987). Soil solarization. In: Innovative approaches to plant diseases control. Chet, I. (ed.). John Wiley & Sons New York. pp 77-105.
- Katan, J., Fishler, G. and Grinstein, A. (1983). Short and long term effects of soil solarization and crop sequence on Fusarium wilt and yield of cotton in Israel. *Phytopathology*. **73**:1215-1219.
- Mahrer, Y. 1979. Prediction of soil temperature of a soil mulched with transparent polyethylene. *J. Appl. Meteorol*. 18:263-267.
- Mahrer, Y. and Katan, J. 1981. Spatial soil temperatures regime under transparent polyethylene mulch-numerical and experimental studies. *Soil Sci*. 131: 82-87.
- Pullman, G.S., Devay, J.E., Garber, R.H. and Weinhold, A.R. (1981) Soil solarization on Verticillium wilt of cotton and soil borne population of *Verticillium dahliae*, *Pythium* spp., *Rhizoctonia solani* and *Thielaviopsis basicola*. *Phytopathology*. **71**:954-959.
- Rao, V. K. and Krishnappa, K. (1995). Soil solarization for the control of soil borne pathogen complexes with special reference to *M. incognita* and *F. oxysporum* f.sp*. ciceri. Indian Phytopath*. 48: 300-303.
- Raoof, M. A. and Nageshwar Rao, T. G. (1997). Effect of soil solarization on castor wilt. *Indian J. Plant Protect*. 25: 154-159.
- Rubin, B and Benjamin, A. 1981. Solar sterilization as a tool for weed control. *Abstr*. *Weed Sci*. *Soc. Am.* p.133.
- Singh, Y. (2008). Effect of soil solarization and biocontrol agents on plant growth and management of anthracnose of sorghum. *Internat. J. Agric. Sci.* 4: 188-191.
- Tjamos, EC. 1984. Control of *Pyrenochaeta lycopersici* by combined soil solarization and low dose of methyl bromide in Greece. *Acta Hortic.* (The Hauge). 152: 253.
- Verma, R. K. Singh, Y., Soni, K. K. and Jamalluddin (2005). Solarization of forest nursery soil for elimination of root pathogens and weeds. *Indian J. Trop. Biodiv*. **13**: 81-86.
- Wagonner, PE, Miller, PM and DeRoo, HC. 1960. Plastic mulching principles and benefits. *Conn. Agric. Exp. Stn. Bull.* 623, 44 pp.

Diagnosis and Management of Bacterial wilt of Solanaceous Crops caused by *Ralstonia solanacearum*

Dinesh Singh
Division of Plant Pathology, Indian Agricultural Research Institute, New Delhi -110 012

Bacterial wilt caused by *Ralstonia solanacearum* (Smith, 1896) Yabuuchi *et al.*, 1995 is highly challenging and one of the most destructive diseases of solanaceous crops including tomato, potato, chilli and brinjal worldwide. The disease is predominant in warm humid tropical and temperate regions of the world (Hayward, 2005). In India, it occurs across the country mainly states of coastal areas, foot hills and lower altitude of hills (Singh et al., 2010). It has a wide host range of about 200 different groups of plants with 50 families, which accounts severe damage to the crops. This wilt disease is a very serious in solanaceous crops. and. The damage caused by this disease to the crop was > 60% depends on environmental conditions and variety of crops. Bringing about severe crop losses worldwide, the disease is now receiving global profile (Allen *et al.*, 2005). It is disturbing agriculture and even trade negotiations in the developing as well as developed world. It is listed as one of the top ten microorganisms affecting agriculture in U.S. Agro-terrorism Protection Act of USDA (2002) and subjected to strict quarantine regulations throughout Europe and America.

Recently, a new classification scheme has been described for strains of *R. solanacearum*, based on comparison of DNA sequences is commonly used for classification studies of strains of microorganism. It is basically assumed that the higher the homology is between two strains, the more closely related the strains are in terms of evolution. These types of studies are known as phylogenetic studies. A sequevar or sequevance variant is defined as a group of strains with a highly conserved sequence within the area sequenced sequevars. A phylotype is defined as a group of strains that are closely related based on phylogenetic analysis of sequence data. Phylotypes were identified within the species that broadly reflects the ancestral relationships and geographical origins of the strains *In R. solanacearum* four phylotype viz., Phylotype I, Phylotype II, Phylotype III and Phylotype IV has been reported by Fegan and Prior, (2005). Each phylotype is composed of a number of sequevars **(**Figure 1**).** Distribution of five races of R. solanacearum, host, biovars and RFLP divisions are presented in Table 1. In India, race 1 biovar 3 and 4 of *R. solanacearum* causes bacterial wilt of solanaceous crops (Table 1). Race 3 (biovar 2) strains are widely distributed in Asia (including Pakistan, India, Bangladesh, China and Philippines) and Middle East countries (Lebonan and Iran). Majority of the strains isolated from Asia belong to phylotype 1. However, Race 3 (biovar 2) strains belonging to phylotype II predominate in South America. In India All major strains reported from India fall under phylotype I and North America Phylotype II (Fegan and Prior, 2005). Main crops affected are tomato and tobacco.

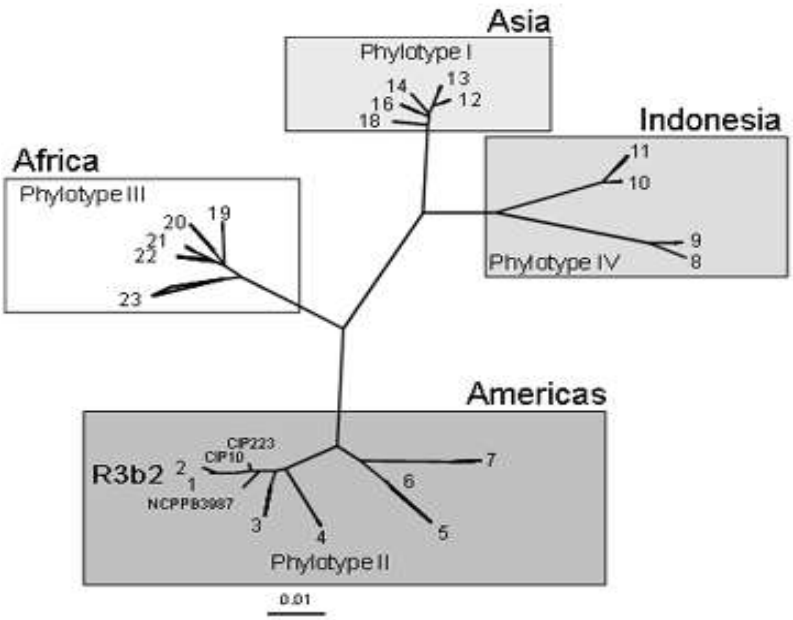


Fig. 1. Classification and geographic origins **of** *R. solanacearum* strains based on sequence analysis of endoglucanase is a type of cellulose, which is class of enzymes produced by fungi, bacteria and protozoans that catalyze the cellulolysis of endoglucanase gene sequences. Numbers indicate sequevars (1 to 23) *(Source :* Fegan and Prior, 2005)

Table 1. Characteristics of races and their relationship to other subdivisions of *Ralstonia solanacearum.*

Race	Host range	Geographical distribution	Biovar	RFLP Division
1	Wide	Asia , Australia, Americas	3, 4 1	I II
2	Banana other *Musa* spp.	Caribbean, Brazil, Philippines	1	II
3	Primarily potato	Worldwide	2	II
4	Ginger	Asia	3, 4	I
5	Mulberry	China	5	I

Diagnosis of Bacterial wilt

1) Disease symptoms

Potato

Foliage symptoms include rapid wilting of leaves and stems usually first visible at the warmest time of day. Eventually, plants fail to recover, become yellow and brown necrotic and die. As the disease develops, a streaky brown discoloration of the stem may be observed on stems above the soil line. The leaves may have a bronze tint. Epinasty of the petioles may occur. A white, slimy mass of bacteria exudes from vascular bundles, when broken or cut. This slime oozes spontaneously from the cut surface of a potato stem in the form of threads, when suspended in water. Under cool growing conditions, wilting and other foliar symptoms may not occur. On tubers, external symptoms may or may not be visible, depending on the state of development of the

disease. Soil may adhere to the tubers at the eyes. Cutting the diseased tuber will reveal a browning and eventual necrosis of the vascular ring and immediately surrounding tissues. Creamy fluid exudates usually appear spontaneously on the vascular ring of the cut surface a few minutes after cutting. The vascular tissues of the stem show a brown discoloration.

Tomato, chilli and brinjal

The wilting symptom of these solanaceous crops can be induced by bacterial and fungal pathogen, root-knot nematode and deficit or excess of soil moisture. The most characteristics symptoms of tomato, chilli and brinjal are very rapid wilting, especially where the plants are young and succulent. The flowering stage is the most critically stage where a plant shows sudden wilting. The first visible symptom is the flaccid appearance of the youngest leaves and in the field. Other primary indications of infection are stunting, downward curling of leaflets and petioles. Usually infected plants collapse quickly, but where this fails to happen there is a development of blackening of vascular system at the junction between stem and leaf. Further down the stem, the whole vascular system may be completely blackened and when cut oozes creamy bacterial slime. Under favourable environmental conditions for the pathogen (soil temperatures of approximately 25 °C; saturated humidity), epinasty and wilting of one side or of the whole plant follows within a few days leading to total plant collapse. Under less favourable conditions (soil temperature below 21 °C), less wilting occurs, but large numbers of adventitious roots may develop on the stem. It is possible to observe water soaked streaks from the base of the stem, which is evidence of necrosis in the vascular system. When the stem is cut crosswise, discoloured brown vascular tissues exude white or yellowish bacterial ooze.

2. Bacterial Ooze test

Ralstonia solanacearum is a limited xylem-invading pathogen and plants wilted by this pathogen have > 10^8 cfu/ g of tissue. A common sign of bacterial wilt of tomato observed at the surface of freshly-cut sections from severely infected stems is a sticky, milky-white exudates, which indicates the presence of dense masses of bacterial cells in infected vascular bundles, and particularly in the xylem, which is responsible for transportation of raw sap (water and nutrients) from roots to aerial parts of the plant. Ooze also may accumulate on the cut surface on the infected surface. Allen *et al.* (2001) reported that even if ooze does not form spontaneously a streaming test may be positive. Other wilt inducing pathogens do not produce comparable ooze. The ooze is usually an almost pure culture of *Ralstonia solanacearum,* which can be cultured on standard, low ionic strength bacteriological media. This water streaming test (Ooze test) is of presumptive diagnostic value in the field.

3. Morphological, biochemical and physiological characters

Ralstonia is a non fluorescent pseudomonas. *R. solanacearum* is in rRNA homology group II where as the fluorescent pseudomonas in rRNA homology group I in 1992, Yabuuchi *et al.,* (1992) transferred even species in rRNA homology group II including *P. solanacearum* into the

new genus *Burkholideria.* Later Yabuuchi *et al.,* (1995) established the genus *Ralstonia* to accommodate *R. solanacearum, R. pickettii* and *R. eutropha.* Gram negative, rod shaped, measuring 0.5-0.7x1.5-2.5 µm, oxidase and catalase positive, accumulate poly-B-Hydroxy butyrate (PHB) and reduce nitrate. Flagella are polar when present. No growth at 40^0C, little or no growth in broth with 2.0% NaCl. Negative for Arginine dihydrolase, gelatine liquefaction and starch or esculine hydrolysis. Defensible brown pigment is produced on complex media. Two type of colonies are observed on complex medium containing 0.5% glucose: fluidal (Mucoid) due to production (EPS), where as other dry (butyrous) (Schaad *et al.,* 2001).

4. Serological methods

In isolating bacteria, *Ralstonia solanacearum* colonies can be confused with saprophytic colonies. Since it is very easy to examine cells from isolated colonies on the medium, agglutination tests can be made and allow a more efficacious screening of the colonies. Otherwise, agglutination tests can be used directly with exudates from several infected plants. In this way, the bacterium can be directly detected in potato, tomato eggplant, sweet pepper and banana. The most commonly used assays for bacteria detection and identification are agglutination, enzyme-linked immunosorbent assay (ELISA), immunofluorescence (van der Wolf *et al.,* 2004), lateral flow strip tests or flow-through assays immunodiagnostic assays using *R. solanacerum* specific. Antibodies (also known as immunoglobulins) are proteins that are used by the immune system to identify and neutralize foreign objects, such as bacteria. Amore subtle detection technique is immunofluorescence, which provides a means for detecting the bacterium in the plant, water and soil. The IF technique can be also used in detecting the bacterium in the host-plant and in studying the rate of spread of the pathogen

Serology techniques are relatively low-cost and easily performed tests for routine *in situ* use. Immunoassays are being applied routinely for the detection of plant pathogens in plant material and soil and tests such ELISA have demonstrated the sensitivity and specificity required to replace time –consuming and expansive assays such as indicator-plant inoculation and dilution plating. Serological techniques also have the advantage that immunoassays are well-established technique s for detection and identification of bacterial species. However, for a rapid reasonably sensitive, assays of total bacterial numbers of a particular species, immunoassays may be the method of choice.

This serological assays so far the detection of pathogen were able to provide information as to the presence or absence of the pathogen in soil and plant, however, they could not discriminate between virulent and avirulent strains of the pathogen and are not specific to strain and races. In this technique, virulent bacterial cells (encapsulated with mucin) from tomato seeds are used as antigen and polyclonal antisera are developed in rabbit using a classified immunization protocol. Antisera thus developed are examined for the antibodies titre, sensitivity, specificity, rapidity and the efficacy of the antibody in identifying the potential for the application of

this assay to the screening of the infected plant materials and seeds. The results indicate that anti-tomato *R. solonacearum* (i) has a good antibody titre of 1:10000 (ii) can detect a few as 100bacterial cells /ml (iii is tomato specific (it reached with tomato *R. solonacearum* and not isolates from chilly (Capsicum) or brinjal (iv)is reactive to all isolates of *R. solonacearum* from tomato (v)is not cross –reactive with non- pseudomonades (vi) is virulent strain specific as it recognizes the virulent exopolysaccharides component an anti-determinants (vii) reactivity could be correlated well with the degree of infection in tomato seeds and plant materials . Thus ELISA developed is sensitive, specific and rapid, therefore, suitable for detection of *R.solanacearum* isolates from tomato seeds during routine assays

Enrichment- ELISA Protocol

In this method, ELISA Protocol, specific monoclonal antibody is used, with prior enrichment of stem greatly, which improves the sensitivity of detection of bacterial pathogens. It is effective because of low sensitivity of ELISA for bacterial detection using specific monoclonal antibodies approximately 105 -106 cfu/ml) and need to improve this sensitivity to detect latent infections of quarantine bacteria. The use of an optimized enrichment for each plant pathogenic bacterium allows its specific multiplication in the sample before detection. Specific protocol is required R. solanacearum (Caruso et al., 2002). The medium temperature, duration and incubation conditions of the enrichment are crucial for optimizing it and improve the detection sensitivity.

On site testing: tissue print- ELISA and lateral flow devices

A simple method is required for rapid detection of plant pathogenic bacteria for testing large number of samples by non- experienced technicians. For this purpose, tissue print ELISA and lateral flow devices have been designed for bacteria. Although detection specificity is very high when using the appropriate monoclonal antibodies. The sensitivity is low for detecting bacteria and they are more appropriate for analyzing plants with symptoms. The lateral flow devices kits are based on existing technology similar to a pregnancy test kit and such kits are only available for few bacteria. A lateral flow device kit developed by Central Science Laboratory, U. K., permits detection of *R. solanacearum* in 3 min, in single step. Rapid ImmunoStrip® is available from Agdia Inc. Immunofluorescence. This technique is widely used in Europe for detection of bacterial pathogens in seed and preparative materials. It is used to screen 60,000 potato pieces annually for the presence of *R. solanacearum* (Danks and Baker, 2000; Van der Wolf and Schoen, 2004**).**

Flow Cytometry

Immunodiagnostic detection has been enhanced by the development of flow cytometry. It can be used for identification and quantification of cells or other particles as they pass individually through a sensor in a liquid stream. Cells are identified by fluorescent dyes conjugated to specific antibodies and multiples cellular parameters are determined simultaneously based on the cells,s fluorescence and its ability to scatter light. The cells may be sorted electronically, permitting

purification and /or culture of subpopulations of selected cells for further confirmatory tests. Sample is prepared as cells suspensions are filtered to remove large particles then stained with fluorochrome – labeled antibodies. Fluorescent markers for viability (vital; stains, such as propidium and hexidium iodide for red fluorescent staining of dead cells and corboxy fluorescein diacetate and calcein AM for green fluorescent staining of viable cells can be used to differentiate live from dead cells (Van der Wolf and Schoen, 2004). This technique has been applied for detection of *R. solanacearum* and to determine viability of bacteria in seed potatoes.

5. PCR based detection and characterization

i. Conventional - PCR (Polymerase Chain Reaction)

In this method, a specific part of the nucleic acid of the target bacterium is artificially multiplied before detection takes place. This multiplication is reached by repeated cycles of denaturation (95^0C), annealing and extension of nucleic acids (72^0C). Theoretically, the sensitivity of PCR is very high i.e. one copy of target DNA in a sample can be detection. However, in practice usually a lower sensitivity 10^3 cells/ml is reached due to inhibitory substances in the plant extract. Although PCR can reach high sensitivity and specificity, its introduction for routine detection has been hampered by a lack of robustness. PCR is the most widely used molecular technique for detection of bacteria. Their main advantages are specificity and rapidity. Specificity is directly related both to the design of the primers or probes and to the amplification or hybridization protocols. The time required until the final result is usually less than 24 h whereas that required for conventional microbiological detection of bacteria was of the order of several days in the case of a negative result and 5–10 days in the case of a positive result due to the tests necessary to confirm it.

Table 2. List of primer sets for identification of *Ralstonia solanacearum* through PCR.

Ralstonia solanacearum	Sequences of primers 5'----------3'	Product size	References
R. solanacearum	Y2: 5'- CCC ACT GCT GCC TCC CGT AGG AGT-3' OLII: 5'- GGG GGT AGC TTG CTA CCT GCC-3'	288bp	Seal *et al.* 1993
R. *solanacearum* and related spp.	759: 5'- GTC GCC GTC AAC TCA CTT TCC-3' 760: 5'- GTC GCC GTC AGC AAT GCG GAA TCG-3'	281bp	Ito *et al*. 1998
R. solanacearum	PS96-H: 5'-TCACCGAAGCCGAATCCGCGTCCATCA C-3' PS96-I: AAG GTG TCG TCC AGC TCG AAC CCG CC-3'	148bp	Hartung *et al* . 1998
R. solanacearum	pehA#3: 5'- CAG CAG AAC CCG CGC CTG ATC CAG-3' pehA#6: 5'- ATC GGA CTT GAT GCG CAG GCC GTT-3'	504bp	Gillings *et al.* 1993
R. solanacearum race 1 and 3 biovar 1, 2, 3 and 4	RALSF:5'-GCTCAAGGCATTCGTGTGGC-3' RALSR:5'-GTTCATAGATCCAGGCCATC-3'	932bp	Kang et al., 2007

Furthermore, the possibility of designing a multiplex PCR saves time and reagent costs compared with monospecific PCR, which requires several reactions for the same number of tests. Colorimetric detection of PCR products, on membranes or in microtitre plates, has been employed successfully, increasing sensitivity and facilitating interpretation of results for the use of the technique in routine analyses. Detection of bacteria in a given sample by PCR is not only

dependent on the performance on the PCR assay itself, but also on the efficiency of the procedure employed to extract the nucleic acids from the plant material. To check for substances that may interfere with the amplification process, internal controls can be designed for each pair of primers, or real-time PCR can be employed. PCR efficiency is controlled by many parameters, such as polymerase type, buffer composition and stability, purity and concentration of dNTPs, cycling parameters as well as the characteristics of the starting template. Several expensive commercial integrated systems allow for the automated extraction and analysis of nucleic acids from microorganisms, but they are not efficient with all types of plant material and need to be evaluated before they can be adopted for routine detection. The specific primers have been designed based on either the amplification of specific genes from the chromosome or plasmids (Table 3) or on different approaches such as sequences selected from RAPD differential bands obtained by subtractive hybridization. Some specific primers have been developed for detection of *R. solanacearum* from tuber, seeds and planting material, soil as well as irrigation is given in Table 2 & 3.

Table 2. Detection *Ralstonia solanacearum* from seed and planting materials by using PCR based techniques**.**

PCR Genomic assay	Host	Detected from	Race / biovar of Bacteria	References
RAPD	Brinjal, chilli and tomato	-	*R. solanacearum* race 3	James *et al*. 2003
16S r RNA	Tomato	-	*R. solanacearum* race 1 biovar 3 and 4	Singh *et al*. 2010.
Fli C	-	soil	*R. solanacearum, R. pickettii*	Schonfeld *et al*. 2003
Nested- PCR	Banana, tomato, chili, eggplant and tobacco	Soil	*R. solanacearum*	Khakvar *et al.* 2008
hrp gene, PCR	Tomato, potato tobacco, eggplant, pepper	Plant and tuber	*R. solanacearum*	Poussier *et al.* 1999
Bio-PCR	Tomato, melon	soil	*R. solanacearum* race 1 biovar 3	Lin *et al.,* 2009
16 r RNA, PCR 16 r RNA, PCR 16 r RNA, Multiplex PCR	- Potato	- Potato tuber	*R. solanacearum* subdivision 2a *R. solanacearum* *R. solanacearum* biovar1, 2, N2, 3 , 4 & 5	Boudazin *et al.* 1999 Pastrik and Maiss, 2000, Seal *et al.* 1999
Multiplex –PCR (16S-23S r RNA ITS)	Potato	Tuber	*R. solanacearum* (Bertolini *et al.,* 2003)	Pastrik *et al.* 2002
Real Time Bio-PCR	Potato	Tuber and plant	*R. solanacearum* race 3 biovar 2	Weller *et al.* 1999; Weller *et al.* 2000
16S r(NASBA)RNA	Potato	Tuber, irrigation water	*R. solanacearum* race 3 biovar2	van der Wolf *et al.* 2004

IC-PCR	Tomato, pepper, weeds (*Physalis minima*, *Amaranthus spinosus* and *Euphorbia hirta)*	Plant and soil	*R. solanacearum race 1*	Dittapongpitch and Surat, 2003
Cytochromec1 signal peptide	Tomato	Soil and plants	*R. solanacearum* race 1 & 3 biovars 1, 2, 3 &4	Kang *et al.,* 2007

ii. Nested -PCR

Sensitivity and specificity problems associated with conventional PCR and RT-PCR can be reduced by using nested PCR-based methods, based on two consecutive rounds of amplification. Usually, the products of the first amplification are transferred to another tube before the nested PCR is carried out using one or two internal primers. The potential of nested-PCR in plant pathology has been already reported (Pradhanang *et al.* 2000). Sensitivity is increased by two orders of magnitude reaching about 10^2 bacterial cells/ml of extract. However, the two rounds of amplification in different tubes also increase the risk of contamination, especially when the method is used on routine in a large scale. One limitation of the nested PCR approach concerns the need to accurately establish the ratio between external and internal primers and the use of limiting amounts of external primers to avoid interference during the second amplification.

ii. Co-operational -PCR

It is a new PCR, which has high sensitivity for the amplification bacterial targets from plant material. The Co-PCR (co-operational amplification) technique can be performed easily in a simple reaction based on the simultaneous action of four or three primers. The reaction process consists of the simultaneous reverse transcription of two different fragments from the same target, one internal to the other, the production of four amplicons by the combination of the two pairs of primers, one pair external to the other, and the co-operational action of amplicons for the production of the largest fragment. Metal block and capillary air thermal cyclers have been employed for the detection of a bacterium, but by using only three primers, which shows the possibilities of this new approach. The low amount of reagents (ten times less than in conventional PCR) probably increases susceptibility to inhibitors. However, this step was not necessary when analyzing the presence of *R. solanacearum* in water. Co-PCR requires only one reaction, minimizing manipulation and reducing risk of contamination.

iii. Real-time (quantitative) – PCR

Quantitative real time PCR has become possible by the development of detectors that can measure fluorescence that is emitted during the PCR cycle. This method is based on the 5'-- > 3' exonuclease activity of the Taq DNA polymerase, which results in cleavage of fluorescent dye-labeled with different probes (TaqMan®) during PCR. The exponential nature of PCR in theory allows the amount of starting material to be calculated from the amount of product at any point in the reaction. In practice, however, reaction conditions can interfere with exponential amplification

and affect product concentration. Early attempts at quantization involved stopping the PCR reaction at various points to generate standard curves, which resulted in a laborious, low-throughput process.

In TaqMan® probe an oligonucleotide probe sequence of approximately 25 -30 nucleotides in length is labeled at the 5' end with a fluorochrome (6- carboxyfluorescein - 6- FAM) and a quencher fluorochrome (carboxytetramethyl- rhodamine -TAMRA), at the 3' end. The probe is degraded by the 5'-3' exonuclease activity of the Taq polymerase as it extends the primer during each PCR amplification cycle and the fluorecent chromophore released. The amount of fluorescence is monitored during amplification cycle and it propotional to the amount of PCR product generated. Real-time reaction monitoring with specific instruments and fluorescent probes combines amplification, detection and quantification in a single step. TaqMan probes consist of single-stranded oligonucleotides that are complementary to one of the target strands. A fluorescent dye adorns the 5' end and a quencher is bound to the 3' end. Fluorescence occurs when the polymerase replicates a template on which a TaqMan probe is bound and the 5' exonuclease activity cleaves the probe. *R. solanacearum*. 100 cfu/ ml of pure culture of *R. solanacearum* was detected by using TaqMan® and the 7700 sequence detection system using either a genus- specific 16 S probe or a biovar 2 specific probe. However, when spiked potato tuber extracts were assayed, the threshold for detection dropped significantly 10^5 and 10^7 cfu/ml with the species specific and biovar 2 specific probes respectively in tuber extracts diluted by 1:10 and in undiluted extract, the threshold was 10^7 cfu/ml because of presence of PCR inhibitors.

iv. Bio- PCR

In this PCR, combine the viable enrichment of mostly growth media with an enzymatic amplification, which is known as BIO-PCR. The target bacterium is enriched in liquid or solid media and detected at extremely low levels in seeds and other propagative materials. The BIO-PCR assay includes the following simple steps as- i) extracting a sample ii) plating a sample onto agar media (half are retained for visual recovery or adding sample to liquid medium iii) incubating for 15 -72h, depending on the growth of target bacterium; iv) washing plates to remove bacteria or centrifuge liquid medium; and using 1 or 10 µl for direct PCR. The samples can be stored at –20^{o}C. This techniques has several advantages over tradition PCR including increased sensitivity of the primer, elimination of PCR inhibition, and detection of viable cells only. It can be used in conventional - PCR or real time PCR. The key to developing a successful real –time BIO-PCR protocol are choose suitable semi-selective or selective liquid or solid medium for bacterium and determine precisely the time for enrichment. In solid medium only pin point size of colony of bacterium may be selected for PCR because larger size (1 mm) of colony may allow to grow other saprophytic bacteria. The most plant pathogenic bacteria are 24 -48 h to grow pin point colonies. However, *R. solanacearum* growing fast and require only 10 -15h. A single pinpoint size colony normally contains over 1000 cells/ ml, which is the threshold for the PCR. Mucoid colony of

bacterium should be avoided for PCR. In Bio –PCR, semi selective medium as SM-1 was developed and further modifying the medium as MAS-1 used for *R. solanacearum*. The detection limit of this medium for through this technique is 100 cfu/ml from soil based on tested artificially or naturally infested soils. *R. solanacearum* was detected from soil of weed rhizoshphere, weed root and water with high sensitivity of detection 1.9 cfu/ ml and 17 cfu/g of soil using bio-PCR.

Management of Bacterial wilt diseases of solanaceous crops

- Use disease free tubers and seeds.
- Treat tubers with streptocycline 500 ppm concentration.
- Grow bacterial wilt resistant varieties of following crops –
  - ✓ Brinjal: Arka Keshav (long type), Arka Nidhi (long type), Arka Neelkanth (long type), Pusa Anupam (round type)and Hissar Shyamal (round type), Singnath.
  - ✓ Tomato: Palam Pink, Palam Pride and F1 7711, Arka Rakshak, Arka Abha, Swarna Sampada
  - ✓ Chilli: Surajmukhi
- Disinfecting the cutting knives with suitable bactericide.
- Avoidance of surface water for irrigation, cutting of potato seeds and education.
- The incidence of wilt diseases in tomato was reduced by applying panchagavya which contains 20 ml of cow ghee, 50 ml each of cow milk, and curd, 40 ml of cow urine, 400g of cow dung, 20 g of common salt and 10g bakers yeast.
- Biocontrol agent *Pseudomonas fluorescens* and *Bacillus subtilis* found effective to control the disease.
- Crop rotation is not effective as the pathogen can survive for a long period (several years) in the soil and also attack a wide range of crops and solanaceous weeds. Crop rotation 2-3 years with wheat and *Crotolaria juncea*
- Do not grow crops in soil where bacterial wilt has occurred.
- Rogue out wilted plants from the field to reduce spread of the disease from plant to plant
- Control root-knot nematodes since they could facilitate infection and spread of bacterial wilt
- Where feasible, extended flooding (for at least 6 months) of the infested fields can reduce disease levels in the soil
- Soil amendments (organic manures) can suppress bacterial wilt pathogen in the soil Good results have been encountered by using biofumigation as soil treatment for bacterial wilt.
- Application of bleaching powder 12 -15 kg/ ha in the furrow during transplanting/ sowing tubers in the field.
- Actigard (acibenzolar-s-methyl) has shown to be effective, but only when inoculum densities are low.

- In India, CRA 66 rootstocks were used in grafting of tomato to reduce bacterial wilt in

tomatoes (Tikoo, 1979). Several Hawaiian lines (Hawaii 7996-7998) have been identified as suitable candidates for resistance to bacterial wilt. This technique could be a very valuable tool for eliminating bacterial wilt in tomato, pepper, and eggplant production systems

REFERENCES

- Allen, C., P. Prior and Hayward, A. C. (2005). Bacterial Wilt Disease and the *RS* species Complex. The American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, Minnesota, U. S. A. p 1.
- Allen, C., Kelman, A., and French, E. R. (2001). Brown rot of potatoes. Pages 11-13 in:
- Compendium of Potato Diseases, 2nd ed. W. R. Stevenson, R. Loria, G. D. Franc, and D.
- P. Weingartner, eds. APS Press, St. Paul, MN.
- Boudazin, G., Le Roux, A. C., Josi, K., Labarre, P. and Jouan, B. (1999). Design of division-specific primers of *Ralstonia solanacearum* and application to the identification of European isolates. *Eur. J. Plant Pathol.* 105, 373–380.
- Caruso, P., Gorris, M. T., Cambra, M., Palomo, J. L., Collar, J. and López, M. M. (2002). Enrichment DASI-ELISA for sensitive detection of *Ralstonia solanacearum* in asymptomatic potato tubers using a specific monoclonal antibody. *Appl. Environ. Microbiol.* 68, 3634–3638.
- Dittapongpitch, V. and Surat, S. (2003). Detection of *Ralstonia solanacearum* in soil and weeds from commercial tomato fields using immunocapture and the polymerase chain reaction *J. Phytopathol.*, 151 (4): 239-246.
- Danks, C. and Barker, I. (2000). On-site detection of plant pathogens using lateral flow devices. *Bulletin OEPP/EPPO Bulletin* 30, 421–426.
- Fegan, M. and Prior, P. (2005). How complex is the "*Ralstonia solanacearum* species complex"? In Bacterial Wilt Disease and the *Ralstonia solanacearum* Species Complex, pp. 449–461. Edited by C. Allen, P. Prior & A. C. Hayward. St Paul, MN: APS Press
- Gillings, M., Fahy, P. and Davies, C. (1993). Restriction analysis of an amplified polygalacturonase gene fragment differentiates strains of the phytopathogenic bacterium
  Pseudomonas solanacearum. Leu. Applied Microbiol. 17: 44 - 48.
- Hayward. A. C. (2005). Research on Bacterial Wilt: A perspective on International links and access to literature. *In:* Bacterial Wilt Disease and the *Ralstonia solanacearum* species Complex. eds. Allen, C., P. Prior and A. C. Hayward. The American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, Minnesota, U. S. A. pp. 1-8.
- Hartung, F., Werner, R., Muhlbach, H. P. and Buttner, C. (1998). Highly specific PCR- diagnosis to determine *Pseudomonas solanacearum* strains of different geographical origins. *Theor.*
  Appl. Genet. 96: 797 - 802.
- Ito, S., Ushijima, Y., Fujii, T., Tanaka, S., Kameya-Iwaki, M., Yoshiwara, S. and Kish, F. (1998). Detection of visible cells of *Ralstonia solanacearum* in soil using a semiselective
  medium and a PCR technique. *J. Phytopathol.* 146**:** 379 - 384.
- James, D., D. Girija, K. Sally, P. A. Mathew, T. D. Nazeem and Varma, A. S. (2003). Detection of *R. solanacearum* race 3 causing bacterial wilt of solanaceous vegetables in Kerala, using random amplified polymorphic DNA (RAPD) analysis. *J. Tropical Agric*., 41: 33-37.
- Kang, M. J., Hee, L. , Jae Kyung, S.shim1, Sang T. S., Rosemary, S., Min Seok, C., Jang, H. H. and Dong, S. P. (2007). PCR-based Specific Detection of *Ralstonia solanacearum*

by Amplification of Cytochrome c1 Signal Peptide Sequences. *J. Microbiol. Biotechnol.*, 17(11), 1765–1771.

- Khakvar, R., K. Sijam, W.M. Yun, S. Radu and T.K. Lin, (2008). Improving a PCR-Based Method for Identification of *Ralstonia solanacearum* in Natural Sources of West Malaysia. *Am. J. Agric. Biol. Sci.,* 3: 490-493.
- Lin, C. H., S. H. Hsu, K. C. Tzeng and Wang, J. F. (2009). Detection of race 1 strains of *Ralstonia solanacearum* in field samples in Taiwan using a BIO- PCR method. *Eur. J. Plant Pathol.* 124: 75 – 85.
- Pastrik, K. H., Elphinstone, J. G. and Pukall, R. (2002). Sequence analysis and detection of *Ralstonia solanacearum* by multiplex PCR amplification of 16S− 23S ribosomal intergenic spacer region with internal positive control. *Eur. J. Plant Pathol.* 108, 831–842.
- Pastrik, K. H. and Maiss, E. (2000) Detection of *Ralstonia solanacearum* in potato tubers by polymerase chain reaction. *J. Phytopathol.* 148, 619–626.
- Poussier, S., Trigalet-Demery, D., Vanderwalle, P., Goffinet, B., Luisetti, J. and Poussier, S., Vandewalle, P. and Luisetti, J. (1999). Genetic diversity of African and worldwide strains of *Ralstonia solanacearum* as determined by PCR Restriction Fragment Length Polymorphism analysis of the *hrp* gene region. *Appl. Environ. Microbiol.* 65, 2184–2194.
- Pradhanang, P. M., Elphinstone, J. G. and Fox, R. T. V. (2000). Identification of crop and weed hosts of *Ralstonia solanacearum* biovar 2 in the hills of Nepal. *Plant Pathol.* 49: 403–413.
- Schaad, N. W., Jones, 1. B. and Chun, B. (2001) *Laboratory guide for identification of plant pathogenic bacteria.* APS Press, The American Phytopathological society, St. Paul, Minnesota.
- Schönfeld, J., H. Heuer, J. D. van Elsas, and Smalla, K. (2003). Specific and sensitive detection of *Ralstonia solanacearum* in soil on the basis of PCR amplification of fliC fragments. *Appl. Environ. Microbiol*. 69: 7248-7256.
- Seal, S. E., Taghavi, M., Fegan, N., Hayward, A. C. and Fegan, M. (1999). Determination of *Ralstonia (Pseudomonas) solanacearum* rDNA in subgroups by PCR tests. *Plant Pathol*. 48:115–120.
- Seal, S. E. , Jackson, L. A., Young, J. P. W. and Daniels, M. J. (1993). Detection of *Pseudomonas solanacearum*, *Pseudomonas syzygii*, *Pseudomonas pickettii* and Blood Disease Bacterium by partial 16S rRNA sequencing: construction of oligonucleotide primers for sensitive detection by polymerase chain reaction. *J. Gen. Microbiol.* 139, 1587–1594.
- Singh, D., Sinha, S., Yadav, D. K., Sharma, J. P., Srivastava, D. K., Lal, H. C., Mondal, K. K., Jaiswal, R. K. (2010). Characterization of biovar/ races of *Ralstonia solanacearum,* the incitant of bacterial wilt in solanaceous crops . *Indian phytopath* 63 (3): 261 - 265.
- Tikoo, S. (1979). Successful Graft Culture of Tomato In Bacterial wilt sick soils. *Current Science*. 48:259-260.
- Van der Wolf, J. M., J.R.C.M. Van Beckhoven, E.G. De Haan, G.W. Van den Bovenkamp
- and Leone, G.O.M. (2004). Specific detection of *Ralstonia solanacearum* 16S rRNA
- sequences by AmpliDet RNA. *Eur. J. Plant Pathol.* 110**:** 25–33, 2004.
- Van der Wolf, J. M. and Schoen, C. D. (2004). Bacterial pathogens: detection amnd identification methods. In Encyclopedia of plant and crop science, R. M. Goodman ed. (New York, USA): Marcel Dekker).
- Van der Wolf, J. M., S. G. C. Vriend, P. Kastelein, E. H. Nijhuis, P. J. van Bekkum, and van Vuurde, J. W. L. (2000). Immunofluorescence colony-staining (IFC) for detection

and quantification of *Ralstonia* (*Pseudomonas*) *solanacearum* biovar 2 (race 3) in soil and verification of positive results by PCR and dilution plating. *Eur. J. Plant Pathol*. 106: 123- 133.

- Weller, S. A., Elphinstone, J. G., Smith, N., Stead, D. E. and Boonham, N. (1999). Detection of *Ralstonia solanacearum* strains using an automated and quantitative flourogenic 5' nuclease TaqMan assay. *Appl. Environ. Microbiol.* 66; 2853-2858.
- Weller, S. A., Elphinstone, J. G., Smith, N. and Stead, D. E. (2000). Detection of *Ralstonia solanacearum* from potato tissue by post enriched TaqMan PCR. *Bulletin OEPP / EPPO Bulletin* 30, 381–384.
- Yabuuchi, E., Kosako, Y., Oyaizu, H., Yano, I., Hotta, H., Hashimoto Y. et al. (1992proposal of Burkholedria gen. nov. and transfer of seven species of the genus Pseudomonas homology group II to the new genus, with the type species Burkholderia cepacia (Palleroni and Holmes 1981) comb. nov. *Microbiol. Immunol.* 36, 1251 – 1275.
- Yabuuchi, E., Kosako, Y., Yano, I., Hotta, H. and Nishiuchi, Y. (1995). Transfer of two *Burkholderia* and an *Alcaligenes* species to *Ralstonia* gen. nov.: proposal of *Ralstonia pickettii* (Ralston, Palleroni and Douderoff 1973) comb.nov., *Ralstonia solanacearum* (Smith 1896) comb. nov. & *Ralstonia eutropha* (Davis 1969) comb. nov. *Microbiol. Immunol.* 39, 897–904.

Planning, Design and Construction of Poly House / Protected Structure

P. K. Singh
Department of Irrigation and Drainage Engineering, G.B.P.U.A.&T., Pantnagar- 263 145 (UK)

Protected cultivation practices can be defined as a cropping technique wherein the micro environment surrounding the plant body is controlled partially/ fully as per plant need during their period of growth to maximize the yield and resource saving. With the advancement in agriculture various types of protected cultivation practices suitable for a specific type of agro-climatic zone have emerged. Among these protective cultivation practices, green house/poly house cum rain shelter is useful for the hill zones. The green house is generally covered by transparent or translucent material such as glass or plastic. The green house covered with simple plastic sheet is termed as poly house. The green house generally reflects back about 43% of the net solar radiation incident upon it allowing the transmittance of the "photosynthetically active solar radiation" in the range of 400-700 Nm wave length. The sunlight admitted to the protected environment is absorbed by the crops, floor, and other objects. These objects in turn emit long wave thermal radiation in the infra red region for which the glazing material has lower transparency. As a result the solar energy remains trapped in the protected environment, thus raising its temperature. This phenomenon is called the "Green house Effect". This condition of natural rise in green house air temperature is utilized in the cold regions to grow crops successfully. However, during the summer season due to the above stated phenomenon ventilation and cooling is required to maintain the temperature inside the structure well below 35°C. The ventilation system can be natural or a forced one. In the forced system fans are used which draw out 7- 9m^3 of air/sec/ unit of power consumed and are able to provide 2 air changes / minute.

Why Protected Cultivation?

⇒ The vegetables / any other produce harvested from the protected cultivation have better quality in terms of the fruit size, per fruit weight, TSS, colour, texture and other quality parameters.

⇒ The productivity of the crop under protected cultivation increases manifold (2-10 times) as compared to conventional system.

⇒ Off-season cultivation of the vegetables/other crops is the most important aspect of protected cultivation. The winter season vegetable crops such as cauliflower, coriander, spinach etc can be grown during rainy season. Similarly, summer season vegetable crops are successfully grown during winter and the winter season leafy vegetable can be grown during summer.

⇒ Under protected environment the incidence of insect and disease are minimized due to its isolation from open field. Use of micro irrigation and off-season cultivation also minimizes the disease and insect incidence. Less infestation of insects and disease offer reduced use

of pesticides.

⇒ The protected cultivation offers efficient use of two most precious resources land and water. Other inputs such as fertilizers, chemicals and labour are also efficiently utilized under such environment.

Protected cultivation technologies

Micro irrigation, raised bed , trellising and staking, mulching, : plastic covered and insect screen covered tunnels, shade nets and insect-proof nets and greenhouses (polyhouses, poly carbonate houses and FRP sheet houses) are the important protected cultivation technologies, wherein the soil and plant micro climatic conditions are modified for better plant growth and high production and quality produce during main/off-season.

Greenhouses: Greenhouse production represents the most intensive of agricultural production systems. Structures require initial capital; energy and labour is high. Under certain conditions, greenhouse cultivation may be equal to highly developed industrial manufacturing operations.

A greenhouse provides:

- Protection against insects – viruses
- Protection against extreme and adverse weather conditions – rain, snow, wind, hails etc.
- Possibilities of controlling crop environment- temperature, radiation, Humidity, CO2

The result: Reliable production and high quality Produce

Common types of greenhouses being used in India

Walk-in tunnels: These greenhouses are good for raising nursery and growing off-season vegetables. With proper technical guidance, these can be built with the help of local artisans, thus minimizing the cost of construction. Utility of walk-in tunnels can be enhanced by using a combination of plastic and insect-proof net as the covering materials. The construction cost ranges from Rs. 150 to 300 / m^2.

Walk-in tunnels as temporary greenhouse structures - These types of greenhouses can be easily installed for short duration use. The structure can be dismantled and stacked conveniently for next season use. The pipe frame is bent with the help of manually-operated pipe bender.

Tunnel type with side ventilation: Higher version of walk-in type, improved ventilation, good for money; construction cost Rs. 200 to 350 / m^2.

Saw-tooth, multi-span: These types of greenhouses provide effective natural ventilation through side and roof vents. These can be used in mildly hot climate for commercial production of flowers, vegetables and medicinal plants. Cost of construction ranges from Rs.450 to Rs.650 / m^2 for naturally ventilated poly-houses and Rs.800 to Rs.1500 for environmental controlled poly-houses. Saw-tooth, tubular structural designs with 4 m gutter height are popular for floriculture and vegetables production. There are several manufacturers of these designs in India.

Curved roof type greenhouses: These designs are simple and can be self-constructed. The cost ranges between Rs. 260 to Rs. 350 / m^2 with good crop schedule, the production system can be

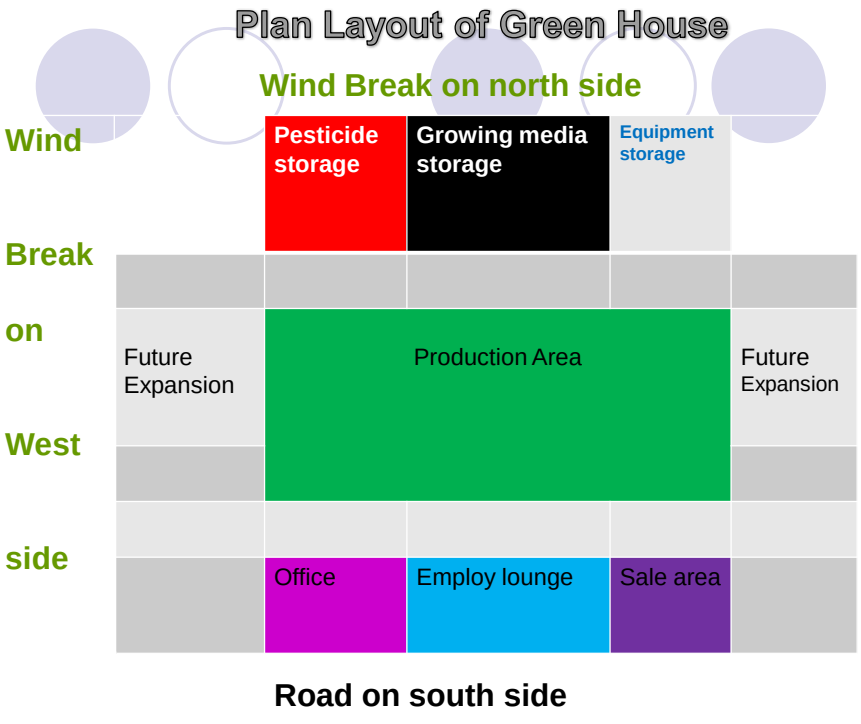
highly profitable

Causes for GH Failure / Damage

- The profile used in the GH frame, trusses and other member too light which deformed by wind
- Cladding material some time appeared to be stronger than structure
- Poly film tearing because of rough and sharp edge of the frame
- The foundation not sufficiently secured against uplift forces
- Damage of polyfilm often started from the ventilation openings

General Considerations for the Planning and Construction of Green House

- A polyhouse is designed to withstand local wind, snow and crop loads for a specific cropping activity.
- In this way the structure becomes location and crop specific.
- The design of a polyhouse structure also depends on the covering material to be used.
- A glass house, for example requires heavier structures to support the weight of glass in addition to other external loads.
- A polyhouse structure should admit adequate quantity of sunlight for crop production in addition to the structure being adequately strong.
- At the same time, the structure should require minimum energy for maintaining desirable crop microclimate.
- The greenhouse design, thus, must be energy conserving while maintaining adequate transparency to solar energy.
- Local climate and local materials must be taken into account to arrive at the most appropriate greenhouse design.



Site Selection and Orientation of Green / poly house

- Ground slope for drainage is an important factor.
- The microclimate condition.
- Adequate provision should be made to divert surface water away from the polyhouse.
- A polyhouse needs a dependable source of energy in the form of electricity and /or other fuel for environmental control.
- An electric power distribution line adjacent to the site will reduce the investment on cable laying.
- A short access to all weather public road will facilitate material handling to and from polyhouse.
- Nearness to the market is another added advantage.
- A dependable supply of good quality water is needed for a polyhouse.
- Polyhouse should be located away from other buildings and trees to avoid obstruction to sunlight.
- Labour availability

Orientation :Two criteria

- The light level in the green house should be adequate and uniform for crop growth
- The prevailing wind should not adversely affect either the structure or operation of the facility

Orientation : Sunlight availability and shading effect

- Single span / Free Standing Green House
    - East-West Orientation
- Multi Span Green House
    - Gutter should be North-South oriented
    - No object taller than 3.3m should be within 9m of the greenhouse in either east, west or south direction

Greenhouse Frame

- The polyhouse frame is the most important component of a greenhouse system.
- It provides support for glazing material and a place for fitting of environmental control equipment.
- Tubular steel sections are the most preferred structural members for greenhouse frames.
- Wood and aluminum are other common materials.
- Wood frame have low initial cost but have high maintenance cost
- Steel pipes provide required strength at a competitive price and also an assured service life of over 20 years.
- Several other single and multispan polyhouse for use in various regions of India have been developed by various PFDCs.

Loads For Greenhouse:

- Green house should be low cost but effective structures.
- Neverthless, they have to withstand outside weather stresses such as storm, rain, hail, and snow (if snowfall occurs).
- The main loads or action to considered are:
- Dead loads or permanent load, self-weight of structural and non-structural elements, excluding the installation even if they are permanently present.
- Wind loads are “action imposed on the structure by wind”
- Snow loads have to considered in the region with snowfall.
- Crop loads have to be considered where structures support crops.
- Where crops are suspended on separate horizontal wires the horizontal tensile forces transmitted to the structure have to be taken into assessment.

Minimum values of GH design loads

	Load	Minimum, kg/sq-m
1.	Dead load :	
	Pipe frame, double PE	10
	Buss frame lapped glass	25
2.	Live load : Fogging / misting system, crop load, mounted instrument etc	25
3.	Snow load	75
4.	Wind load	Depending on prevailing wind speed

Design requirement:

- The general design requirement for plastic-film greenhouses are:
- Sufficient stability against wind and crop loads. That means sufficient dimension of the construction component, and installation of wind braces.
- The connection and connectors between the different construction component must not move or slide by load forces.
- The foundation under the stanchions have to endure pressure and suction forces by wind.
- The plastic film must not flutter by wind forces. It has to be stretched and fixed tightly on the structure.
- Drops of condensed water should not fall down from the inner surface of the film onto the plants, but they have to run off at the film.
- Gutters are necessary to drain off and collect the rainwater.
- Windbreaks should be installed if the wind velocity is too high.

Greenhouse Environmental Control

- A greenhouse is essentially meant to permit at least partial control of microclimate within it.

- The control of greenhouse environment means the control of temperature, light, air composition and nature of the root medium.
- Obviously, a control over all these parameters makes a greenhouse a completely controlled.
- However, in general, greenhouse with partial environmental control are more common and economical.

Ventilation and Cooling

- A greenhouse is ventilated for either reducing the very high greenhouse air temperatures or for replenishing carbon dioxide supply or for moderating the relative humidity in the greenhouse.
- It is quite possible to bring greenhouse air temperature down during spring and autumn seasons by providing adequate ventilation for the greenhouse.
- The ventilation in a greenhouse could either be natural or forced.
- In case of small greenhouse (less than 6 m wide) natural ventilation could be quite effective during spring and autumn seasons.
- However, fan ventilation is essential to have precise control over air temperatures, humidity and carbon dioxide levels.
- Orientation of the greenhouse is another important factor.
- An east-west oriented free standing greenhouse maintains better winter light level as compared to a north-south oriented greenhouse.
- Therefore, in north India, a greenhouse should be oriented in east-west direction. Gutter connected greenhouse should be oriented north-south to avoid continuous shading of certain portions of the greenhouse due to structural members.
- A greenhouse structure has three distinct segments i.e. frame, grazing material and control / monitoring equipment.
- All the three components have different designed life periods.
- Whereas a metallic greenhouse frame is designed for a service period of 15 to 25 years, grazing materials have a life span of 2-20 years.
- Control and monitoring equipment normally wear out in 5-10 years.
- In the prevailing economic conditions, where capital is a scarce input, the choice often favours low initial investment greenhouse.
- Galvanized mild steel pipe as a structural member in association with wide width UV stabilized polyethylene film is a common option selected by greenhouse designers.
- A 600-800 gauge thick polyethylene film can safely withstand normal wind loads prevailing in most parts of the country.
- A single piece polyethylene film to cover greenhouse is preferred due to material economy, easy handling and improved environmental control.

- A 800 gauge thick polyethylene film costs approximately Rs. 60-80 / square meter and has a service span of 2-5 years.
- The selection of greenhouse equipment depends on local climate conditions and the crops to be grown. A heating unit is a must in cold regions and a cooling unit is required in almost all climates in India.

Cooling Systems

- While ventilation may be used for cooling during autumn and spring seasons, other methods have to be employed for cooling during summers.
- Roof Shading
- The amount of solar radiant energy entering the greenhouse can be reduced by applying opaque coatings directly to the glazing or by placing wood or aluminium in-the over the glazing.
- Commercial shading compounds or mixtures prepared with paint pigments are preferred for this purpose.
- White compounds are preferred for they reflect a maximum amount of sunlight, 83% xx versus 43% for green, 25% for blue or purple.

Water film on the greenhouse cover

- To absorb infrared radiation, a water layer must be at least 1.0 cm thick.
- But on sloping greenhouse roof, it is limited to about 0.05 cm which is not thick enough.
- Cooling is most effective when cold water is used in the water film.

Evaporative Cooling (EC)

- The degree of cooling obtained from an evaporative system is directly related to the wet-bulb depression that occurs with a given set of climate conditions.
- EC systems are most effective in areas where a consistently low relative humidity exists.

Fan and Pad System

a) It is adaptable to both large and small greenhouses.
b) In this system, low velocity and large volume fans draw air through wet fibrous pads mounted on the opposite side or end wall of the greenhouse.
c) The outside air is cooled by evaporation to 20^0C of the wet-bulb temperature.
d) Either vertical or horizontal pads can be used in the F and P systems.
e) However, vertical pads accumulate salts, sag rand, thus, create openings that allows hot air to enter the greenhouse.
f) Various materials, viz. gravel, pine bark, straw, burlap, aspen wood fiber (shredded populus tremuloides mats), honey comb paper etc. can be used for the pad.
g) However, pumice and Volcanic rock (1-4 cm in dia) are reported to function very satisfactorly.

High-pressure mist system

- Water is sprayed into the air above the plants at pressures of 35-70 kg /sq.cm. from low capacity nozzles (1.8 to 2.8 lit / h).
- Although most of the mist evaporates before reaching the plant level.
- Some of the water settles on the foliage where it reduces leaf temperatures.

Low-pressure mist system

- Misting with water pressure at less than 7 kg / sq.cm have achieved air temperature 50C cooler in a greenhouse compared to natural ventilation.
- The water droplets from a low pressure misting system are quite large, and do not evaporate quickly.
- Leaching of nutrients from the foliage and the soil is a serious drawback of using this technique.

Humidity Control

- For most crops the acceptable range of relative humidity is between 50% - 80%. However, for plant propagation work, relative humidities upto 90% may be desirable.
- Humidification in summers can be achieved in conjunction with greenhouse cooling by employing appropriate evaporative cooling methods, such as fan-pad and fogging systems.
- Sometimes during winters when sensible heat is being added to raise the greenhouse air temperature during nights the relative humidity level might fall below the acceptable limit.

Greenhouse Heating

- There are essentially three main categories of efforts needed to maintain desirable greenhouse temperatures during winter.
    - design of energy efficient greenhouse with passive solar heating components.
    - design of active heating systems based on renewable energy sources such as solar and biogas.
    - design of active heating system based on conventional fuels.
    - While the conventional fueled based heating systems are many and dependable, the other two categories of efforts are still evolving.

Heating systems based on conventional fuels

- Traditionally, glass greenhouse have been heated by hot water systems. Most larger commercial greenhouse are heated with some type of boiler system.
- Gas fired unit heaters for greenhouse heating, deliver heat at approximately half of the cost of the steam / hot water systems. The hot air is distributed through a perforated poly-tube running along the greenhouse length.
- Electric heaters, both radiative and convective, are simple and convenient to control. But, the nonavailability of electricity and its high cost limit its use to small and / or experimental greenhouse.
- The heating systems should not only raise the greenhouse temperatures but should also

achieve uniformity of temperature distribution. Therefore, placement of heating units and the type of distribution system to be selected are important.

Heating Systems Based on Non-Conventional Energy Sources

- A number of active solar heating have been developed for greenhouse during the last two decades in order to feduce the dependence of greenhouse industry on conventional fuels.
- The normal components of a solar heating system are :solar collector, heat transfer medium, heat exchanger, and heat storage.
- Biogas, generated from agricultural wastes/residues, can also be used for greenhouse heating.

Design of Passive Solar Greenhouse

A passive solar greenhouse is one which not only attempts to capture maximum solar energy but also minimizes the unwanted thermal exchange between the greenhouse and the surroundings in order to maintain desirable temperatures, The following points summarize the useful results so far:

1. A greenhouse should be oriented east-west.
2. The north side of a greenhouse structure should be thermally, insulated.
3. The north side of a greenhouse facing the crop should be covered with a reflective surface so that the sunlight incident on it from the south side is reflected on to the crops.

REFERENCES

- NHB. 2005. 2005. National Horticulture Board, Indian Horticulture Data Base 2005.pp361.
- Annonymous. 2008. Annual Report: 2007-08. Precision farming Development Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India, pp 105.
- Singh, B. 1998. Vegetable production under protected condition: Problems and Prospects. Indian Society of Vegetable Science Souvenir: Silver Jubilee, National Symposium Dec.12 14, 1998, Varanasi, U.P. India, pp 90.

Management of Greenhouse Mites

Naved Sabir
National Centre for Integrated Pest Management, New Delhi

Greenhouses in India are suffering from serious pest infestations mainly sucking pests and soil borne pathogens Among them Spidermites, belonging to Acari (mite) family Tetranychidae, which includes about 1,200 species, occupy a significant position and are common pests in many vegetable as well as ornamental crops. They generally live on the undersides of leaves of plants and feed by puncturing the plant cells. Spidermites are known to feed on several hundred species of plant and can inflict serious damage to trees, shrubs and flowers. Spidermites are not insects but are more closely related to ticks and spiders. They have four pairs of legs, no antennae and a single, oval body region. Their common name is derived from their ability to produce silk, which most species spin on host plants. They are very minute in size which is why infestations often go unnoticed until plants exhibit significant damage once they multiply rapidly.

Name of pest mites	Scientific name	Crops affected
Two-spotted spidermite	*Tetranychus urticae*	Many vegetables (tomato, cucumber, capsicum) and ornamentals (rose, gerbera)
Carmine spidermite	*T. cinnabarinus*	Tomato and carnation
Broad mite	*Polyphagotarsonemus latus*	Many vegetables and ornamentals
Cyclamen mite	*Phytonemus pallidus*	Mainly strawberry and cyclamen
Tomato russet mite	*Aculops lycopersici*	tomato

Symptoms of Damage

- Mites feed on the cell sap on the underside of the leaves
- Speckling or mottled appearance and yellowing of leaves
- Damaged leaves become pale, brittle, and parchment-like and fall from the plant
- Heavy infestations results in loss of plant vigour and death of plants
- Form webs of fine silk on plant terminals in severe infestations

Key Pest: Two-Spotted Spidermites *Tetranychus urticae*

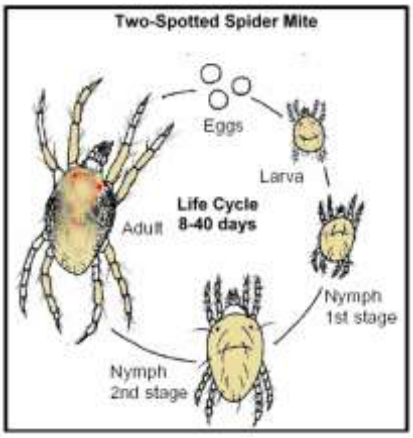
The most devastating pest on cucumber is two spotted or red spidermite *Tetranychus urticae,* belonging to the family Tetranychidae. Spidermite females lay down the webs on the underside of the leaves and live in the colonies. When numbers are extreme, webbing can easily be seen on the whole plant especially on the growing tips. These mites feed by first puncturing the cell and then sucking up the juices. The early symptoms of mite damage are visible as a silvery white flecking or speckling where the mites are feeding, usually along the midrib. Extensive damage by them eventually makes the leaf bronzed, in severe cases the leaves may wither and die. Two spotted mite attack a broad range of plants, from most vegetable crops, ornamentals, tree crops and weeds and frequently occur in protected environments such as glasshouses. It is extremely polyphagous pest attacking more than 200 crops.

Two-spotted spidermite

Damage Symptoms and webbing of mites in cucumber

Life cycle:

The egg of *T. urticae* is translucent and pearl-like. It hatches into a nymph, which in turn develops into a protonymph, and then a deutonymph. Depending on mite species, temperature, host plant humidity etc the development from egg to adult often takes one or two weeks or more. Males not only develop faster than females, but guard and fight for deutonymph females. The male who wins, mates with the female soon after its emergence. Haploid males are produced from the unfertilized eggs. Fertilized eggs produce diploid females which survive the winter in diapause. Spidermites can reproduce throughout the year in the closed environment of greenhouse. The adults are typically, pale green orange or yellow in colour, but later generations are red in colour; the two spotted mite hatches in 3 days at the temperature of 27^{o}C , into first stage larvae having only three pair o



Temp. ^{o}C	Duration of spidermite life cycle
<10 ^{o}C	Development stopped
13 ^{o}C	36 days
23 ^{o}C	13
30 ^{o}C	7
35 ^{o}C	6
>40 ^{o}C	Development stopped

f legs. The larvae feed for few days and molts into first nymphal stage which has four pair of legs. It then molts into second nymphal stage which turns into adult. Depending upon the ambient temperature and other biotic and abiotic factors the life cycle may vary from 6 days to 40 days. Life cycle tends to stop below 10^{o}C and 40^{o}C. Life cycle is faster at higher temperatures and hence in greenhouses under Indian conditions the multiplication of spidermites is alarmingly rapid. Under favourable conditions the spidermites can complete 5-6 generations per year.

Spidermite eggs that have not yet hatched are impermeable to most miticides; the same is true of larvae and nymphs that are moulting. During moulting, spidermites remain immobile

beneath the older cuticle therefore the insecticides prove ineffective in controlling them. The dormant mites also do not feed, therefore the products that kill by ingestion proves futile. Consequently, if only one application is made, some of the mites may survive and the infestation will persist.

Traditonal management and their constraints

The warm, humid conditions and abundant food in a greenhouse provide an excellent, stable environment for pest development. In closed systems the pest situations reach the alarming level with great severity within no time as the natural enemies which control the pest are not present in the greenhouse.

Several factors are responsible for successful control of insect pests on greenhouse vegetables and ornamentals. Proper cultural practices, early detection and diagnosis and proper choice of selective pesticides can minimize the chance for initiation and build-up of infestations.

Traditional management of pests generally involves pesticides that are specially developed for pest control but resistance development is the most severe challenge to pest control. Most of major pests today are characterized by very high pesticide resistance levels to various types of active ingredient. A number of insects and mites have achieved global pest status due to pesticide resistance combined with the intensive international trade in plant material. Greenhouses being a closed system face this problem frequently as population of selected strain is not thinned by outdoor wild population making the control difficult. There can also be detrimental effect of these chemicals on non target species resulting in pest outbreaks and phytotoxic reactions by treated plants.

The pesticide resistance and then consumer and environmental concerns are forcing growers to replace simple pesticide based control programme by other, more sophisticated and tactically broader integrated control systems.

Biorational Management

- Spray Azadirachtin @ 2%
- Spray horticultural oil @ 1%
- Apply calmite @ 2 ml/L
- Apply abamectin (vertimec) @ 0.5 ml/L as last resort due to high cost

Insecticidal Soap -- 1-2.5 gal/100 gal.

Paraffinic Oil -- 1-2 gal/100 gal.

Neem Oil -- 0.5-2% in 25-100 gal water per acre.

Neuronal inhibitors (unknown mode of action).

Bifenazate (PHI, 3 days; REI, 12 hrs). For various mite species. Registered only on tomato varieties greater than 1 inch in diameter. ***Floramite***: 3 g/10 L approx.

Chemical Control

Chemical	Trade name	
Abamectin	Avid	-Broad mites -Cyclamen mites -Eriophyid mites -False spidermites -Two-spotted mites -Mites (general)
Bifenthrin	Talstar	-Broad Eriophyid False spider Two-spotted
Bifenazate	Floramite	-Red and two spotted sipder mite
Chlorofenapyr	Pylon	-Broad -Cyclamen -Eriophyid -False spider -Two-spotted
Chlorofentazine	Ovation	-Two-spotted
Deltamethrin	Deltagard	-Mites(general)
Dicofol	Kelthane	-Broad -Cyclamen -Red and two spotted sipder mite
Etoxazole	Tetrasan	-Red and two spotted sipder mite
Fenbutatin oxide	Vendex	Twospotted spidermite
Fenpyroximate	Akari	-Red and two spotted sipder mite
Fluvalinate	Mavrik	Twospotted spidermite
Hexithiazox	Hexigon	Broad and two spotted spidermite
Pyridaben	sanmite	Two spotted spidermite
Propargite	Ornamite	Red and twospotted spidermite
Spinosad	Conserve	Red and twospotted spidermite
Spiromesifen	Forbid	Broad -Cyclamen -Eriophyid -False spider -Two-spotted

Scope of biological control

A potent alternative to chemical control is biological control which is defined as the use of living organisms to control pests. These may be Predators, parasites, parasitoids, pathogens or naturally competitive organisms.

Biological control is a natural phenomenon of pest suppression by natural enemies The populations of natural enemies and their host and prey tend to maintain an equilibrium in nature once this equilibrium is broken phytophagus insects and mites tend to reach high densities causing grevious losses to the farmers Although the use of chemical pesticides can present high immediate effectiveness they also present collateral effects. Insecticides and miticides besides being toxic for pest organisms are toxic to natural enemies, man and domestic animals.

The main reason behind using biological control methods were the concerns about risk of chemicals for environment and human health. They mainly target the specific pest,may work at a

slow pace in the beigning but offers longer term management than the more traditional technology areas and the cost for control is lower relative to more traditional control procedures. Typically, biocontrol agents are released in relatively low numbers for only a short time in the beginning of the program unlike more traditional methods of control which are used continually over many years.

To ensure the success of any biological control programme it should be be used preventatively when the pest populations are still low. A regular monitoring programme is needed for early detection of pest. In case of spidermites they should be introduced at hotspots as soon as the pest is detected .Delaying the introduction is a major factor in programme failure.

Natural enemies of insects and mites:-

From the economic standpoint, an effective natural enemy is the one which is capable of regulating the population density of the pest, maintaining it below the economic damage level established for a given crop. In general the natural enemy should present the following characteristics; it should comply with environmental physical conditions changes, should be specific to the host; should have a high searching capacity, especially at low densities of host, should have seasonal synchronization with host and should be able to survive in absence of host.

In case of pest insect and mite control, the major natural enemies are the insects, known as entomophaghus. The entomophaghus group is represented by predators and parasitoids.

Parasitoids: - are insects that develop on or within the host. They require only one host to complete their life cycle from egg to adult and kill the host when their cycle is completed. The parasitoids are the most effective natural enemies for biological control. Parasitoids are found in different insect orders however in Diptera and especially in Hymenoptera this group has become abundant. The great host diversity in different habitats makes the hymenoptera parasitoids one of the most important groups for biological control.

Predators: - A predator is an organism that lives by preying on other organisms and destroys it for its own gain. Several insects and mites are predators during their whole lifecycle. A predator usually hunts the most abundant insects that they can find in any environment.*Phytoseiulus persimilis and Amblyseius californicus* belonging to family Phytoseiidae are two important predatory mites used for the control of spidermites,besides this a predatory bug *Macrolopus caliginosus* is also an efficient biocontrol agent

Natural enemy/Predatory Mites, *Phytoseiulus persimilis*

This mite is a natural predator of spidermites and was one of the first greenhouse biological control agents available commercially. It is red shiny pear shaped mite with long legs, slightly larger than its prey and moves very fast. It is an indigenous species of Mediterranean region which was accidentally introduced from Chile. The eggs of *P. persimilis* are oval and orange in colour. Larvae and nymphs are pale and

translucent at first but become orange after feeding. Adult females are slightly larger than males. It is host specific preferring the eggs and young stages of its prey. An adult female can consume ten to twenty spidermite eggs per day. Its development takes about 5 days at 30°C, The female lays 2–6 eggs per day and during life cycle it lays about 106–108 eggs. The life span of the predator is 20–25 days. This mite requires a relative humidity of greater than 60% in order to survive especially in egg stage This fast development is an important factor in its success as a predator. The initial ratio of pest to predator decides the outcome of a control programme, therefore the initial dose of the predator must be sufficient to achieve control before the damage is done, how ever the control can be unsatisfactory at very high temperatures and low humidities, great thing about this species is that it dies after the spidermite population is gone, cannibalizing on each other.

Release Methodology

Introduction

- Turn and shake the bottle gently before use
- Sprinkle material on leaves or pour into application boxes
- In low crops, it is possible to distribute predatory mite packing mechanically by means of the mite blower

Environmental conditions

Relative humidity should be greater than 75% and the temperature above 20°C/68°F for some hours of the day. Phytoseiulus persimilis does not enter diapause.

Storage and handling

- storage after receipt: 1-2 days
- storage temperature: 8-10°C/47-50°F
- in the dark (bottle horizontally)

Appearance

Adults: bright red, very active, spherical, stands high on its legs

Eggs: oblong, first pink and transparant, later on darker, twice as big as spidermite eggs

Larvae/nymphs: pale to light red

Mode of action

Adult predatory mites and nymphs search actively for their prey and suck them dry.

Visual effect

Adult red spidermites that have been eaten change colour from brown to black (in tomato) and can be identified as tiny black dots on the leaves. This should not be confused with living, light-brown to dark-red spidermites.

For hotspots

Release Rates				
Phytoseiulus persimilis	**rate**	**interval (days)**	**frequency**	**remark**
Preventive	2/m²	21	-	-
Curative light	6/m²	7	1-2x	-
Curative heavy	20-50/m²	7	2x	introduce in infested areas only

REFERENCES

- Deka S., Tanwar R.K., Sumitha R., Sabir N., Bambawale O.M. and Singh B. 2011. Relative efficacy of Agricultural Spray oil (Servo Agrospray ®) and Azadirachtin against two-spotted spidermite, *Tetranychus urticae* Koch on cucumber under greenhouse and laboratory conditions. *Indian Journal of Agricultural Sciences*. 81 (2): 156 - 160.
- Onzo, A. Houedokoho, A. F. Hanna, R. 2012. Potential of the predatory mite, *Amblyseius swirskii* to suppress the broad mite, *Polyphagotarsonemus latus* on the gboma eggplant, *Solanum macrocarpon*. *Journal of Insect Science* (Madison); 12: 7.
- Pruszynski, S. Domagal, T. Piatkowski, J. Kosmalski, W. 1989. New elements in integrated programmes of greenhouse crop protection. [Polish] *Materialy Sesji Instytutu Ochrony Roslin*. 29: 1, 175-183.
- Tomczyk, A. Suszko, M. 2011. The role of phenols in the influence of herbal extracts from Salvia officinalis L. and *Matricaria chamomilla* L. on two-spotted spidermite Tetranychus urticae Koch. *Biological Letters*. 48: 2, 193-205.
- Zhang ZhiQiang. 2003. Phytoseiid mites. Mites of greenhouses: identification, biology and control. 171-202.

A Glimpse of Mushroom Science & Technology

S.K. Mishra
Department of Plant Pathology, G.B.P.U.A&T., Pantnagar- 263 145 (UK)

The knowledge of science and engineering collectively has made possible to mushroom to bea highly protected proteinaciouscrop. The growing and production habit of mushroom is principally based on their species, organic substrates,solid and liquid state fermentation, temperature, light and humidity. These all together are easily integrated in a defined volume of space by anyone if that has an outstanding knowledge of mushroom biology, principles, bio-techniquesand handling of sophisticated equipments along with work experience. The mushroom activities e.g. collection of mushroom, spore print, tissue culture, pure culture, master spawn, commercial spawn, cultivating techniques of mushroom, crop husbandry, disease, insect and disorder management, post-harvest management, value addition and disposition of spent mushroom substrate are performed under controlled conditions by man himselfwithout being much affected by nature's governance that make mushroom a fully protected low volume high value crop. The whole approach as above collectively termed as mushroom science and technology (MST) in view to obtain mushrooms and or by-products thereof. MST has distinguished features, describe under following headings

Scope of MST

A. **MST in Nutrition:**Indian people have cereal based diet which is deficient in protein. Additional supply of deficient protein in our diet is possible from mushrooms.They are well known for good quality protein and considered to be a complete health food for all age groups. Protein content of mushroom is usually high but varies from 12-35% species wise. The digestibility of mushroom protein is higher than the pulse protein. Alike the protein content the dietary fiber (8-10%), vitamins (Folic acid, Thiamine, Riboflavin and Niacin) and essential minerals (Cu, Zn and Mg) are other important nutritional components of mushroom. Ideal proportion of sodium and potassiumof mushroom extract is enough to reducehypertension. Mushroom minerals also improve the blood circulation. Total carbohydrate is varied from 26-82% on dry weight basis in different mushroom. Edible mushrooms commonly have trace amount of fat with ergasterolthat act as precursor for the synthesis of vitamin D in human body. Mushroom also contains 80-90% water content that supports proper blending of dietary components in soluble form. In underdeveloped countries where protein malnutrition has taken epidemic proportions, Food and Agricultural Organization has recommended mushroom foods to solve the problem of malnutrition.

B. **MST in Medicine:** MST also promotes the study of medicinal mushrooms and their bio molecules with the help of medical practitioner and pharmacologists and mandatory rules of medical science. Medicinal uses of mushrooms areas old as their nutritional uses. They are beingused in medicine since the Neolithic and Paleolithic ears (Samorini, 2001). The Greek

physician Dioscorides of Ist centaury included lurch polypore (*Fomitopsisofficinalis*(Villars: Fr.) Bond and Singer, Polyporaceae in his De Materiamedica known then as Agaricum and later as the Quinine conk. It was used for the treatment of tuberculosis. Though mushroom have been used in China for medicinal purposes since 100 AD (Gunde, 1999). Most of the mushroom drugs are now available in tablet form in China (Yang et al., 1993).The modern thinking about the medicinal properties came late in 1960 to investigate basic health promoting active principles. Specific biochemical compounds of mushrooms are responsible for improving human health in many ways. These bioactive compounds include polysaccharides, tri-terpanoides, low molecular weight proteins, glycoproteins and immunomodulating compounds. These chemicals have been shown to boost immune system against several antigens, lower down the risk of cancer, reduce inflammation, induce the antioxidant mechanism of our system and to regulate digestive system.The medicines of mushroom origin can also control various diseases. According to Bahl (1983) mushrooms can cure epilepsy, wounds, skin diseases, heart ailments, rheumatoid arthritis, cholera besides intermittent fevers, diaphoretic, diarrhea, dysentery, cold, anesthesia, liver disease, gall bladder diseases and used as vermicides.The mushroom medicine also act asanti-allergic andanticholesterolemic (Jiskani, 2001).

C. **MST in Agriculture:**Innately MST not supports only to organic farming and its sustainability but also supports to other agro-business like poultry production, animal husbandry, agriculture and some industries of chemicals, fertilizers and organic by-products (wheat bran, sawdust etc.).Year round seasonal cultivation of mushroom is possible by growing different mushrooms in different months. By this way growers can generate full time employment to themselves and their family members. Mushroom cultivation does not require any fertile land of cultivation so landless farmers can grow mushroom in their small rooms. The collective farming of mushroom is more beneficial than single cultivating unit in order toupliftment of livelihoodof poor people as they can get good marketing solutions and ultimately employment generationwith mutual.

D. **MST in Ecology:** MST purelybelieveson conservation of natural resources by two different ways: (1) mushroom mycelium transforms hardy degradable rather polluting organic substances into valuable foodstuffs e.g. mushroom fruits and mushroom mycelium (Beyer, 2005, Noble, 2005), (2) use of fungi/mushroom mycelia as tool for healing soil, what Stamets (2005) termed “mycorestoration”in which‘fungi/mushroom repairs or restores damaged biosystems’. Mycorestorationincludes the selective use of mushrooms, to filter water(mycofiltration), to enact ecoforestrypolicy (mycoforestry), to denature toxic wastes(mycoremediation)and to control insect pests and diseases (mycopesticides). Thus, MSTdirectly pacts withclean and balance environment.

E. **MST in Bazaar:** As per FAO statistics global mushroom production was estimated at about 2.18 to 3.41 million tons over period of last 10 years (1997-2007). This is incessantly increasing with the rate of 0.3-3.41 million tons over the period of about last 50 years from 1961-2010. Out

of 11 mushroom producing countries China, USA and Netherland are three major ones. They share more than 60% of the world production. China is a largest producer and consumer of the mushroom. It accounts for 45.81% of total world mushroom production, just half of the world mushroom production. About 5% of its total domestic mushroom production is exported and rest 95% is consumed by China itself. Per capita consumption of mushroom in China is more than 10 kg/person/year in comparison to 3kg/person/year in many European countries.

In India mushroom industry is one of the emerging agribusinesses and about 90% mushroom economy of India is dominated by button mushroom and rest 10% is subjected to the *Pleurotus* and other specialty mushrooms like*Calocybeindica, Auricularia, Volveriella*etc.Indian mushroom industry hasseasonal and hi-tech status.About 60-70% of total *Agaricus*production is restricted to few hi-tech mushroom growing industries. However, rest amount of production is being produced by seasonal growers during winter. Our country contributes about more than 1 lakh ton (3% of the world mushroom production). Out of 28 states and seven union territories Panjab ranks first in mushroom production followed by Utarakhand and Haryana. In Indian conditions the cost : benefit ratio of mushroom production at seasonal growing scale is about 1:2. It increases by 1:4-5 ifmushrooms are grown for whole year at large scale with hi-tech facilities.

Phases of MST (Mushroom-biotech)

Mushroom bio-tech requires several precise phasespurely based on scientific facts.Each previous procedure is essential to the next one andall collectively performs the success in mushroom biotechnology. Any missing or faulty practice may cause trouble, which could lead to a substantially reduced mushroom yield or products and their marketing values.The majorsteps involvein mushroom bio-techniques are: (a) collection/selection of desirable mushroom fruits; (b) raising pure culture; (c) spawn preparation; (d)construction of crop room/huts; (d)preparation of selective substrate; (e) crop husbandry and protection; (f) post-harvest management and (g) recycling of Spent Mushroom Substrate (SMS).

a. **Collection/Selection of desirable mushroom germplasm:** The selection of mushroom germplasm ratherdifficult but can be made easy if, mushroom growers have ample knowledge of species. Selection can be made for higher yield, long fruiting time, long shelf life, attractive size, solid texture, colour, flavourand aroma and resistance quality to adverse climatic conditions, pests and diseases. Local as well as international market, purpose of cultivation (research, nutritional and medicinal), availability of substrates, status of mushroom industry (high-tech or seasonal) and environmental requirements for growth and fruiting of mushrooms which can be met without excessively costly systems of mechanical control are other important factors that may also consider during strain selection.After all mushroom culture must perform the desirable trait to its best genetic potential undersuitable growth conditions.
b. **Raising pure culture:** Pure culture of mushroom can be raised by microscopic spores and

tissue culture. Spores are collected in form of spore print by which multispore and single spore isolation is done.Spore culture technique is generally useful onlyin breeding programmes and genetic improvements of mushroom species. Some single-spore isolates made from homothallic mushrooms, e.g. *Volvariellavolvacea* (primary homothallism) or *Agaricus bisporus* (secondary homothallism) can be directly used as fruiting culture. However, if single-spore isolates, obtained from heterothallic mushrooms, e.g. *Lentinulaedodes*, *Pleurotus sajor-caju*and *Ganodermalucidum*, are not fertile. They have to be mated with a compatible single-spore isolate to produce dikaryon/fruiting culture which later on used in spawn making. Readymade pure fruiting culture can also be obtained from any mushroom laboratory.The tissue culture is a very simple technique and preservegenetic purity of valuable cultures. In this methoda piece of healthy tissues is taken from immature mushroom fruit and placed centrally on the surface of the medium with a sterilised needle for vegetative growth. About ten days later the myceliumwill grow rapidly and cover the surface of the agar medium. Fully colonized test tubes can be stored at low temperature for further use.

c. Spawn Preparation: Technique of spawn making comprises high cost equipments with scientific knowledge and sound skill. Spawn itself explains as a master/mother spawn for first generation from whicha second generation commercial spawn is prepared to sale. About 10kilograms of boiledwheat grains are mixed with 120 g gypsum (CaSO4. $2H_2O$) and 30g calcium carbonate ($CaCO_3$). The gypsum prevents the grains from sticking together and calcium carbonate is necessary to correct the pH. The prepared grains are filled into half-litre milk / glucose bottles at the rate of 150-200 g per bottle (by three-fourth capacity) and autoclaved at 20-22 lb. psi (126^oC) for 1 ½ to 2 hours. Sterilized bottles are shaken to avoid clumpformation,while hot and allowed to cool down overnight. Next day, bottles are inoculated with bits of fruiting culture and then incubated at 21±2^oC. Periodic shaking of bottles is done for proper distribution and colonization of mushroom mycelium on to the wheat grains. Mycelium completely permeates the grains within 2-3 weeks. The master spawn becomes ready for further multiplication of second generation spawn. About15-25 spawned grains of master spawn are transferred in thermostable polypropylene bags that contained 300-500g sterilized wheat grains. Rest method of commercial spawn is same as master spawn.

d. Construction of crop room/huts: Mushroom being an indoor crop does not require arable land except to construct crop rooms. In India mushroom production is done at seasonal and high-tech industry level. In seasonal cultivation pukka ordinary rooms are required. These rooms are generally made by brick walls and do not require insulation. Cropping room for seasonal growing can also be made with thatched roof and false polythene ceiling. In these rooms and hutsmushrooms are raised on beds made by bamboos sticks and sarkanda stems. These seasonal growing rooms are varied in the volume. About 10x8x10 ft sized room or thatchis enough to accommodate 4-6 quintal compost prepared from long method of

composting with at least 3 quintal wheat/rice straw.

The high-tech crop rooms are insulated and built with manual or semi-automatic operating systems to maintain the range of temperature, humidity and air circulation as required by the crop. The dimension of cropping room is determined by the amount of compost to be filled into rooms. Generally 60x17x13 ft volumetric space accommodates 20-25 ton compost when cultivation is done in shelves or bags. High-tech growing rooms are well equipped with insulated boundaries (walls and roof), insulated doors/vents, light arrangement, water connections, drainage channels, racks, air handling units etc.

e. **Substrate preparation:** Unlike the vegetables, mushrooms are heterotrophic in nature and capable to draw nutrition from lignin and cellulose based organic substrates. But due to inherent variations for the requirement of carbon and nitrogen and different biologic demands of mushroom species they need selectivetechniques of substrate preparation with identical C:N ratio and pH. In cultivation of about all major edible and medicinal mushrooms generally wheat straw and paddy straw are one of the major substrates.*Agaricus bisporus* grows on compost made by these substrates. However, *Pleurotus* prefers a crude un-composted fresh substrate.*Lentinulaedodes*favours the medium that contains saw dust. In the same way other mushrooms prefer different technology of substrate preparation.

f. **Crop Husbandry and Protection:**Crop husbandry of mushroom starts from spawning to disposition or reuse of spent mushroom substrate. In between them spawn run, casing, CAC'ing, pinning, thinning, cropping, picking, diseases and insects management are other important steps which have to employed successively along with needful adjustment in temperature and humidity inside the crop rooms.

g. **Post-harvest Management:**Mushrooms are highly perishable in nature and get spoiled very soon at ambient temperature. High moisture content, fleshy and succulent body texture, enzymatic browning and bacterial infection are the major causes of reducing quality post-harvest life of mushrooms. Such mushrooms are loose in colour, toughness, flavour and aroma and thus not find suitable both for meal and sale. To extentpost-harvest life of mushrooms several techniques and practices have since been developed. Sun drying is one of the simplest and oldest methods followed by the growers from the time immemorial. New preservation techniques like canning, pickling, mechanical and chemical drying (freeze drying, fluidized bed drying, batch type cabinet drying, osmotic drying, oven drying) and irradiation treatment of mushrooms are developed to strengthen the post-harvest life of mushrooms (Wakchaure, 2011).

h. **Recycling of spent mushroom substrate (SMS):** SMS is a remaining organic substrate of mushroom production industry that left after full crop of mushroom has been harvested. It loosely stipulated to the spent compost of button mushroom but all growing mushrooms produce their own kind of fresh SMS with different biological, chemical and physical properties.

However, 1-3 years old SMSs (mature SMS) are almost identical with their properties and found very useful as soil conditioner and organic fertilizer to the soil and crop plants, respectively. Bioremediation of contaminated soil and water, encouragement of beneficial actinomycetes, bacteria and fungi in soil, plant disease management, re-growing of mushrooms are other important aspects of mature SMS, Fresh SMS is also useful as value added substrate of biocontrol agents, animal fodder, biogas, steam production etc. therefore, MST purely favours the recycling of spent mushroom substrate incessantly because it otherwise creates various environmental problems including ground water contamination and nuisance if not handled properly.

Conclusion

The purpose of the present study is that mushroom related activities (MRA) would not define as mushroom cultivation, rather it has broad area of study under nutrition, medicine, agriculture and ecology in order to achieve social, economic and environment friendly consequences. On the other hand MRA can be explored only with the help of collective approach of mushroom biology (science) and engineering (technology). So, it would be rationalized that MRA isnow being termed as Mushroom science and technology (MST). It is self-explained and works onthe principle of solid and liquid state fermentation technology with involvement of basic inputs likemushroom species, their supporting substrates, temperature and humidity. It is area of research under which various permutations and combinations ofthese inputs should be studied not only for our benefits but also for the environment health. All areas of MST have series of phases and require a set of scientific and technological knowledge to be completed for examplemushroom production in the crop room is one of the major objectsstarted from choice of desirable mushroom fruits to recycling of spent mushroom substrate (SMS) as mentioned in the beginning of this chapter. Similarly crop husbandry is the result successiveevents. Above all events are based on techniques, so they always are under the governance of manhimself. Though MST is thriving worldwide day by day but with challenges of low acceptability by the people, fast depletion of mushroom/fungal biodiversity due to urbanization, polluting environments, deforestation, climate change; Lack of good quality mushroom species, complicated technologies involve in MST and unknown biology of mushrooms. These challenges can overwhelm with future strategies based on the promotion of mushrooms among the people, genetic resources enhancement of mushrooms, refinements and validation of techniques, study of medicinal chemical compounds and recycling of SMS.

REFERENCES

- Beyer D (2005). Spent mushroom substrate (SMS) research in the US. AMGA J. Summer Issue: 31-32.
- Noble R (2005). Spent mushroom substrate –an alternative use. AMGA J. Summer Issue. 33-35.
- Stamets P (2005). Mycelium Running: How Mushroom Can Help Save the World. Ten

SpeedPress, Berkeley and Toronto, 574pp.

- Samorini G (2001). Fungi Hallucinogeni. Studietnomicologici. Telesterion. Dozza Ed., Bologna, Italy, Shen (Guo J, Cheng HY, Wei X. eds.), pp. 250.
- Gunde-Cimmerman N (1999). Medicinal value of the genus Pleurotus (fr). P Karst (Agaricaless.l. Basidiomycetes). Int. J. Med. Mush., 1: 69-80.
- Yang QY, HU YJ, LI XY, Yang SX, LIU JX, Liu TF, XU GM, Liao LM (1993). A New Biological Response Modifier - PSP. (In: CHANG ST, BUSWELL JA , CHIU SW (eds.) Mushroom Biology and Mushroom Products. The Chinese University Press, Hong Kong, pp. 247-259.
- Bahl N (1983). Medicinal value of edible fungi. In: Proceeding of the International Conference on Science and Cultivation Technology of Edible Fungi. Indian Mushroom Science II, pp. 203-209.
- Jiskani MM (2001). Energy potential of mushrooms. Dawn Econ. Bus. Rev., p. 4.
- Wakchaure GC (2011). Postharvest handling of fresh mushroom. In: Mushrooms-cultivation, marketing and consumptio. Singh M, B Vijay, Kamal S and Wakchaure G C (eds.) DMR, Solan. 197-206.

Tomato Production in Greenhouse

J.P. Singh
Department of Vegetable Science, G.B.P.U.A.& T., Pantnagar-263 145 (UK)

Improved flavor and shelf life are the driving force for the increased demand for greenhouse grown tomatoes. Consumers love the taste of a fresh tomato, and they are willing to pay a premium price, especially in the winter. Unlike field-grown tomatoes which require harvesting and marketing over a short period of time (3-4 weeks), greenhouse tomatoes are harvested and marketed over a 30-week period.

Greenhouse tomatoes can be produced with minimal use of pesticides. Hot water treatment of the growing medium should kill weeds, fungi, and bacteria. Installing screens on the greenhouse vents, using sticky cards, and biological pest control can minimize or eliminate the use of pesticides.

Projected gross income per year from one greenhouse of the size mentioned earlier should equal or exceed the gross income from one acre of field grown tomatoes. Net income can be higher if no hired labor is needed.

Who should consider growing greenhouse tomatoes for a profit?

Someone who

- Is willing to work few hours every day for at least 300 days a year.
- Pays attention to details.
- Having an excessive zeal for sanitation.
- Is a good sales person.
- Lives near by the greenhouse.

Greenhouse location

- Should be away from trees which harbor aphids, white flies, spider mites, and block sun light.
- Have an access to good roads and markets.
- Site should be higher than surrounding area to allow for drainage.
- Should have an access to electricity , natural gas, heating oil or any other source of fuel.
- Must have a good water source, each plant will need at least 100 gallons of salt-free water a year. Before building a greenhouse, send a water sample to a well-known laboratory to determine salt contents. Acidity and alkalinity of water should be determined as well. the best source is rain water and it is easy to collect 2000 gallons of water from one inch of rain falling on a roof of a 30X96 feet greenhouse if equipped with gutters and a collection system.

Greenhouse orientation and size:

- North/south orientation is a must.
- Cooling pads should be installed on the north side and exhaust fans on the opposite side.

- A 30 feet wide by 96 feet long greenhouse is popular.

Greenhouse frame cover

- Light inside the greenhouses is relatively weaker than outside (65% of outside light or less). The reduction of inside light is caused by some light reflection off the greenhouse and interception of light by the covering material and greenhouse frame.
- During winter, the sun's angle is low and a lot of light is being reflected off the greenhouse. It was reported that during conditions of low light, a 1% reduction in light can cause a 1% yield reduction.
- Greenhouse cover has a strong effect on light transmission and light quality. Glass absorbs most of the UV radiation, while polyethylene allows more UV transmission. Greenhouse plastic film with an ultraviolet and infrared barrier, as well as anti-drip properties should be used. Choose material that allows the maximum possible light transmission to plants inside, especially during the winter months.

Improving light transmission into the greenhouse

- Once or twice a year, especially before and during the winter season, wet the top of the greenhouse with a mix of water and a cleaning agent.
- Use a wet flannel cloth to wash the wetted top of the greenhouse in a seesaw motion then rinse with plain water (better if done during cloudy days).

Greenhouse ground cover

- A concrete floor is the best solution for preventing weed growth and general sanitation inside the greenhouse.
- It allows for pressure washing of the floor with hot water between crops to kill diseases and insects.
- However, few growers can afford to have a greenhouse with a concrete floor. If we do not have a concrete floor, make sure to cover the ground with black type cloth to prevent weed growth and top it with a white layer to improve light reflection inside the greenhouse.

Heating the greenhouse

- Night temperature should be at least 63 °F and not higher than 68EF and day temperature should be between 75 and 80 °F. Night temperature above 70 °F impairs fruit set because it reduces pollen and ovule viability and day temperature above 85 °F does the same thing and reduces fruit quality because of poor color and fruit cracking.
- Bottom heat is more efficient than top heat. Warm air will rise between tomato plants leading to dry leaves (no condensation) and less disease problems.
- Heating the growing medium to 70°F is very important to activate the roots and improve yield. Use natural gas, butane, or heating oil.

Cooling and ventilating the greenhouse

- Evaporative cooling pads installed on the north side of the greenhouse and exhaust fans of

appropriate size and power installed on the opposite side are needed to cool the green house.

- Cooling pads should be kept clean of green algae. Dry the pads completely on regular bases whenever possible. Use a T shaped dull object to scrape salts and dry algae from the exposed surface of the pads. Be careful not to destroy the pads. Reverse the pads by turning them around once every two years.
- Reduce sunlight exposure of the pads using a porous black shade cloth and use a black sump tank with a black cover.
- Keep your greenhouse full of plants whenever possible. On a sunny day, a full grown tomato plant will lose approximately one quart of water through transpiration. This loss of water can lower the temperature of the house by at least 10 ºF.
- Use small fans (20 in. diameter) operating continuously above the plants. Half the number of fans should push the air in one direction on one side of the house and the other half should do the same thing in the opposite direction on the other side. Run the small fans non-stop 24 hours a day.
- Leave some vents opened at night to let some fresh outside air enter the greenhouse to reduce condensation. Closing all the vents at night to save energy may lead to the build up of ethylene gas as a by-product of heating and may lead to flower abscission and/or reduce the shelf-life of the fruit.
- Use anti-drip material sprayed on the interior surface of the plastic or use a plastic cover containing anti-drip properties as part of its formulation to help reduce dripping of moisture into the plant Eliminating condensation and reducing humidity should reduce the incidence of botrytis and reduce the need for fungicides.
- Condensation on the fruit may cause minute cracks to develop on the skin. Fruit moisture lost through the cracks will shorten fruit shelf life.

Using shade cloth to cool the greenhouse

- Shade cloth is not effective in providing significant reduction of air temperature inside the greenhouse. A 50% shade cloth may lower air temperature by 3 to 4EF.
- However, shade cloth will provide a significant reduction in sunlight entering the greenhouse.
- Most of the light absorbed by the fruit turns to heat leading to poor color and fruit cracking.
- Reducing light during summer will not retard plant growth because there is more than enough light for the photosynthesis process, but it can reduce leaf and fruit temperature leading to improved plant growth and fruit quality.

Growing medium

- Except for the nutrient film technique (NFT), a growing medium consists of solids and pore space.

- Coarse medium is made up of larger particles with fewer, but larger spaces.
- A fine medium has many, but small pores.
- The size of particles and distribution of pores are important factors to determine the physical characteristics of the medium.
- Total pore space and size determines the rate of drainage and gas exchange. A portion of this space is occupied by air.
- Plant roots require oxygen for growth and adequate aeration of the medium is necessary. A good soilless medium should have a good retaining ability of water, enough space for air exchange, and good drainage rate. Following are examples of some growing medium:

I. Soil

- Soil media is the worst choice for growing greenhouse tomatoes because it does not provide the optimum moisture and aeration at the same time.
- Disease, salts, and waste buildup in greenhouse soil is a limiting factor for long-term profitable production.
- Repeated use of greenhouse soil to grow tomatoes will lead to significant losses because of diseases, insect, and salt build-up
- It is not easy to sterilize greenhouse soil and there is no occasional heavy rain to wash off excess salt and plant waste.

II. The Nutrient Film Technique (NFT)

- It is a water culture system where a shallow stream of nutrient solution covers the roots of growing plants to provide water, nutrients, and oxygen.

III. Soilless media

- Rockwool, polyurethane, pine bark, and perlite are examples of soilless media that are used for growing greenhouse tomatoes.

1. Pine bark

- Bark is a by-product of the timber industry.
- Before it can be used as a growing medium, it has to be composted to balance its carbon/nitrogen content, get rid of the harmful compounds, and kill insects and disease.
- For successful composting, the bark must be thoroughly watered and conditioned with nitrogen, then left to compost for at least three months with occasional turn over.
- During decomposition, compounds which inhibit growth are reduced and temperature increases to about 150°F. Never use green pine bark to grow greenhouse tomatoes.
- It was a good growing medium if used for a maximum of two years. It was difficult to clean the bark with hot water and reuse it indefinitely. Also, it was obvious to us that controlling the pH in the root zone was not an easy task because of the continues decomposition of the bark.

2. Perlite

- Perlite is a volcanic mineral crushed to small pieces and heated to 2000 °F.

- The small quantity of water trapped inside the small pieces turns to vapor during heating and puffs out the perlite pieces.
- Expanded perlite is white, lightweight, and inert. It is capable of retaining water, air, and nutrients and it provides optimum air-water relationship.
- Perlite is a good growing medium and it can be reused for many years.

Tools for Success

Greenhouse tomato growers should strive to maximize their production from a limited space area. To achieve their goal, growers have to purchase and know how to operate several tools to avoid making serious mistakes during the course of production.

1. Thermometers

- A minimum/ maximum thermometer is a must for greenhouse tomato growers.
- Temperature in the greenhouse has a great influence on nutrient uptake, plant growth, pollination, fruit set, fruit cracking, etc.
- Locate the thermometer at the center of the house and at the plant level not facing the sun.
- Every effort should be made to keep temperature within the acceptable range for maximum yield and quality (63-68 °F at night and 75- 80 °F during the day). Night temperature above 68 °F and day temperature above 85 °F will lead to poor production of pollens and poor fruit set and fruit color.

2. Humidity meters

- Best pollination can be achieved when humidity ranges between 60 and 80%.
- Less than 60% relative humidity can result in a dry stigma and reduce germination of the pollen grains and fruit set.
- Growers should use these meters to adjust for the desired level of relative humidity.
- Condensed moisture on the leaves can have an impact on the spread of botrytis disease.
- High relative humidity in the greenhouse will result in less transpiration leading to less movement of calcium to the fruit and a higher incidence of blossom end rot.
- The damage caused by botrytis with minimum or no use of fungicides can be achieved by running the horizontal fans continuously, periodic running of the exhaust fans, allowing fresh air to enter the greenhouse even in rainy days.
- Good sanitation is a must.

3. pH meters

- Ideally the pH of the nutrient solution should be between 5.6 and 6.3.
- Growers should invest in buying a good quality pH meter and regularly check the pH of the nutrient solution as well as the pH of the growing medium.
- Wait about one hour after irrigation and use a sampling tube to take a sample to a depth of 5 to 8 inches from 5 growing bags selected at random and gently squeeze the nutrients and measure the pH. Do this once a week or every two weeks at the most.

- The pH meter should be calibrated before use to assure accurate readings.
- Solubility of mineral nutrients, particularly micro-nutrients, is dramatically affected by media pH.
- Iron, manganese, boron, copper, and zinc are most soluble below pH 5.5 and may be available at toxic levels if the pH is below 5.0.
- At low pH, hydrogen ions saturate media exchange sites and increase the potential for leaching and losing nutrient cations such as calcium, magnesium, potassium, and ammonium.
- High media pH can cause micro nutrient deficiencies even when the micro nutrients are there.
- Chlorosis of the upper portion of the plant is often caused by high media pH.

4. Electrical conductivity (EC) meters

- These meters are used to estimate soluble salts in water which are usually measured by their electrical conductivity. EC meters express EC as millimhos per centimeter (mmhos/cm), deciSiemens per meter (dS/m), or milliSiemens per centimeter (mS/cm). They are equivalent units of measure.
- Analysis should be made for the nutrient feed solution and for the root medium.
- The EC measurement alone does not indicate the types of fertilizer in the nutrient solution, but this measurement can provide a good indication of the total amount of fertilizer being applied.
- A root-zone EC of above 2.5 mS/cm should alert growers that salt buildup is becoming serious and flushing the growing medium may be necessary. It is important to know the water's EC before mixing the fertilizer and if it is high for the tomato crop, it may be necessary to find another source or to purify the water. An EC of 1.5 to 2.5 mS/cm is good for a mature tomato crop.

Starting a tomato crop

Selecting a variety

- Generally indeterminate type growth habit is suitable for greenhouse conditions. Do not use varieties developed for field production in the greenhouse. The seeds are cheaper, but they are less adapted to greenhouse low light conditions and disease pressure.
- Two varieties suitable for greenhouse conditions developed from Pantnagar viz. Pant polyhouse bred tomato-2 and Pant polyhouse hybrid tomato-1. Himsona, Badshah, Vaishali are few indeterminate cultivars from private sectors doing well under greenhouse conditions.

How many crops to raise every year?

The long season crop

- Seeds were planted in germination trays in late September.

- One crop per year will let you harvest tomatoes continually between December and the end of June of the following year.
- Per plant production will drop in January and February because of the many cloudy days during these two months. Total plant production was less than the combined fall and spring crop production. Also, it should be noted that a long season crop becomes more susceptible to disease and insect problems as the plants get older. Pest management is more difficult and more expensive on older plants than younger plants.

Feeding greenhouse tomato plants

- Tomatoes require at least 15 essential elements for maximum growth and yield.
- Potassium nitrogen, phosphorus, calcium, magnesium, and sulfur are needed in larger quantities.
- Minor elements such as boron, iron, manganese, copper, zinc, molybdenum are essential but needed in smaller quantities.
- The bulk of the tomato plant consists of carbon, hydrogen, and oxygen. These elements are obtained from the air and water.
- Greenhouse-grade fertilizers are generally preferred over standard grades because they have high purity and solubility.
- Small growers are encouraged to buy pre-mixed fertilizers to avoid making mistakes in preparing the mix themselves.

Care on fertilizer application

- Do not use a high rate of N to feed your greenhouse tomatoes. In general, we used 100-120 ppm nitrate-N to feed our mature tomato plants with good success.
- Too much nitrogen can result from increasing the rate of application and/or increasing the volume of irrigation with low concentration of nitrogen. Flushing the bags will be necessary to leach out the excess unusable fertilizer.
- The use of ammoniate nitrogen for greenhouse tomatoes has been correlated with a higher incidence of blossom-end rot. Ammonium can cause potassium and calcium deficiency leading to blossom-end rot.
- On hot days, plants will need more water to keep up with water loss through transpiration.
- Using a fertilizer solution with a high EC will reduce water uptake by the roots leading to more stressed tomato plants.
- High soluble salts impair the ability of roots to take up water and nutrients.
- Root injury from high salts can lead to root rot.
- Wilting or burning of leaves and a reduction in post-harvest quality are typical symptoms of high salts.
- Reducing the EC of the nutrient to1.0 mS/cm was good for feeding our tomatoes in hot weather and an EC of 1.5 to 2.5 mS/cm was good for feeding in cool weather

- Some fertilizers contain salts like potassium chloride or sodium nitrate, which supply undesirable elements along with the nutrients. Tomato plants use very little sodium or chloride and too much of these elements can severely stress tomato plants, especially during hot weather.
- All the salts from water, fertilizer, and media that are not used by the plant will be left in the soilless medium. If they are not leached out regularly, they will accumulate and pose several problems including misinterpretation of the EC values.
- To alleviate this problem, it may be necessary to flush the growing medium as needed with acidified plain water (pH of 5.5 - 6.0), especially when the EC of the growing medium is higher than 2.5 mS/cm.

Spacing greenhouse tomato plants

- Each tomato plant should have at least four square feet of greenhouse space. Multiply the length by the width of the greenhouse and divide by four to get the number of tomato plants you can plant in a greenhouse. A 30x96 ft greenhouse should have enough space for 700 plants.
- Accurate spacing is essential for uniform distribution of light.
- North- south orientation of the rows is desirable.

Supporting and training greenhouse tomato plants

- Single-stem tomato plants can grow up to 30 feet in height and can have a load of 4 Kg of fruit at any given time.
- The weak stem requires a strong support system to carry the heavy load.
- A strong wire cable of 3/32 inch diameter should be stretched over each row of tomato plants at a height of 8 feet and supported by a strong greenhouse frame or metal posts.

Pruning of greenhouse tomato plants

Suckers

- Prune tomato plants to a single stem by removing all side shoots or suckers at least once a week. Remove the suckers early in the morning on sunny days when they are very small (one inch or smaller). The small wound resulting from removing the sucker will heal quickly leaving less chances for fungal invasion. Also, prune the suckers or leaves growing on the flower clusters.

Leaves

- A great percentage of assimilates are typically supplied to the fruit by the two or three leaves under the fruit cluster.
- Early removal of these leaves will hinder the growing fruit from reaching the desirable size.
- However, removal of the leaves under the fruit cluster will speed up the ripening process, improve air circulation, and reduce botrytis disease incidence. The fruit should be in the mature green stage before removing the leaves under it.

Flowers

- Normally the flower clusters are not pruned until 3 to 4 well-formed fruit appears on that cluster.
- However, abnormal flowers (the large fasciated flower) have to be removed as soon as recognized. This flower will produce a cat-faced fruit.

Fruits

- Fruit pruning is very important to get the large size desired by the consumer.
- Leave 3-4 well formed and defect free fruits per cluster. Do the pruning as early as possible to reduce competition between growing fruit.
- Remove all deformed fruit, excess fruit, and flowers by snapping and not pinching the holding stem. In general, greenhouse tomato plants should not carry any fruit other than the nice looking large size fruit.

Terminal points

- Remove the terminal growing point above the top flower cluster (last cluster to pollinate) approximately forty five days before the intended date of terminating the tomato crop to stop plants from continuing to grow.
- Leave 2-3 leaves above the top cluster to shade and feed the top fruits.
- During hot summer months and leaving as many leaves on the plant can provide good shade for the growing fruit and cool the greenhouse.
- It is estimated that each plant will transpire close to 1-1.5 lit. of water a day and a house full of plants can lower the temperature of the greenhouse by at least 10 °F.

Pollination

- The female organs of the tomato flower are enclosed inside the male organs (five anthers attached together to form a cone around the female organ). Anthers open to the inside releasing pollen as soon as they mature.
- At maturity, the anthers will have a bright yellow color and the flower will be receptive to pollination for about 48 hours.
- Pollen released without vibrating the flower will not be sufficient to produce high yield of good quality fruit. Field tomatoes are pollinated (vibrated) by natural wind. Because natural wind is absent in the greenhouse, tomato growers must pollinate their crop by several means including battery operated vibrators, air blowers, and bumblebees.
- Growers should also make every effort to transfer the maximum number of pollen to the stigma of the flower.
- The size and weight of the tomato fruit is positively correlated with the number of pollen transferred to the female part of the flower.

Battery operated vibrators

- Vibrators are small devices which can be purchased from any greenhouse supply store

and operated by a weak electrical current from a battery.

- Vibrate the flowers by touching the stem of the flower cluster for few seconds. The strong vibration created by this tool will release more than enough pollen to fertilize the majority of the eggs in the ovary.
- Pollinate the flowers every-other-day on sunny days when humidity in the greenhouse is between 60 and 80%. Touch the cluster stem and do not touch the flower itself otherwise a hole will be created in the developing fruit. It takes approximately 30 minutes three times a week to pollinate 700 plants in one greenhouse of size 30X96 feet.
- This method of pollination is good for a small-size operation and the best method to guarantee pollinating every flower you want to pollinate and produce maximum-size fruit.
- Some of the drawback includes the fact that a grower has to be in the greenhouse at a certain time three times a week, it is a boring job, and the possibility of producing fruit with holes if you touch the flower.

Air blowers

- Greenhouse tomatoes can be pollinated by using a household leaf blower operated at normal speed with the air flow directed to the flower clusters.
- Use this device three times a week.
- It takes half the time to pollinate the same number of plants compared to the electric vibrator.
- However, the number of seed per fruit was less and fruit size and weight were smaller than fruit produced by using the vibrator for pollination.
- In general, anticipate five percent reduction in yield if you use this device.

Bumblebees

- Using bees to pollinate one or two greenhouses will save you time to do something else but it will not save money.
- Bumblebees are excellent pollinators for greenhouse tomatoes. Each bee will visit and vibrate the flower for few seconds to collect pollen for feeding. As a by product of this process, the stigma of the flower is showered with a large number of pollen leading to good pollination and fertilization of almost all the eggs in the ovary.
- Larger size and a heavier fruit is expected from bee pollination. Bees are active from sunrise to sunset, they do not take a long break or a day off.
- It is estimated that each bee can pollinate up to 350 flowers.
- Using a hive (even the smallest mini-hive) can lead to over pollination and injuring many flowers in a small greenhouse.

Disease Management

- High humidity and warm temperatures are congenial for disease development in greenhouse.

- Common diseases of greenhouse tomato
    1. Gray mold
    2. Leaf mold
    3. Powdery mildew
    4. Tomato spotted wilt virus

1. Gray mold

- Caused by the fungus Botrytis cinerea.
- A light-gray fuzzy growth that appears on stems and leaves.
- Soft rot of the stem end of the fruit can also occur.
- Most severe in greenhouses with moderate temperatures, high humidity, and stagnant air.

Management

- Increasing ventilation and air circulation to reduce humidity levels can be helpful, as well as timely fungicide applications.

2. Leaf mold

- Caused by the fungus Fulvia fulva, in humid greenhouses with poor air circulation.
- Appears on lower leaves as yellow spots on the upper surface and fuzzy masses of buff-colored spores on the underside.
- These leaves drop prematurely as the disease progresses upward on the plant.

Management

- Lowering greenhouse humidity, planting resistant varieties, and applying fungicide promptly can be helpful in leaf mold management.

3. Powdery mildew

- Caused by the fungus Oidium neolycopersici
- Common in humid greenhouses with poor air movement.
- White patches on the upper surface of leaves, defoliation as the spots develop into brown lesions.

Management

- Increase air circulation and spacing between plants
- Fungicide sprays also can be effective if used when symptoms are first noticed.

4. Tomato Spotted Wilt Virus

- The virus is spread primarily by thrips, particularly the western flower thrips.
- Leaves get blackish-brown circular spots, or tan spots bordered by a black margin.
- Fruit gets orange to yellow spots surrounded by a green margin.

Management

- Control the virus is by controlling the thrips vector through insecticides.
- Do weed control to minimize the population of thrips and virus.

Harvest and storage of tomatoes

- Harvest greenhouse tomatoes every other day early in the morning when greenhouse

temperatures are low and fruit quality is better.

- Do not leave the harvested tomato in the greenhouse in a sunny location even for a short time.
- Harvest the fruit as soon as you see some color developed on the blossom end (breakers or turning).
- Fruit harvested at any of these ripening stages has enough internal ethylene to continue the ripening process on it's own if stored at 20-22 °C.
- Light is not needed to finish the ripening process. Fruit harvested at the red ripening stage will be subject to severe bruise without appreciable amount of extra quality.
- Leaving the fruit on the tomato plant to reach full color may result in higher percentage of cracked fruit and more fruit with yellowish color if the greenhouse temperatures were above 29 °C.
- Do not store tomatoes at temperatures below 15.5 °C.
- Vine-ripened tomatoes should not be refrigerated.
- Higher EC of the growing medium will enhance fruit quality and shelf life but may reduce fruit size.
- High humidity can lead to the production of transparent fruit and fruit with minute cracking leading to a significant reduction in fruit shelf life.

Marketing greenhouse tomatoes:

- Do not grow greenhouse tomatoes unless you have a market ready for them. Vine-ripened tomatoes can be stored for a short period of time (4-5 days) before quality deteriorates. Only good quality fruit will keep the customers coming. When tomatoes are boxed, fruit at the bottom of the box should be as good as at the top. Separate the culls and sell them to an informed costumer at a discount price.
- Tomatoes produced in a higher EC medium will taste much better than tomatoes produced in a low EC medium but higher EC may reduce yield. Tomatoes produced in December, January, and February will taste much better than gassed tomatoes but fruit taste will be enhanced in March, April, and May.
- The quantity and quality of sun light available in the spring is responsible for better flavor (sugars, acids, aroma, etc.) produced by the plant during these months. Higher prices are common during the winter months, but total production per plant is reduced.
- Light is the limiting factor and if you clean the plastic to allow more light to enter the greenhouse you should be able to enhance production.
- Be creative in your marketing techniques; greenhouse tomatoes can be shipped in decorated boxes during occasions.

Climate Change and Plant Diseases

Suresh Pande
International Crops Research Institute for the Semi-Arid Tropics Patancheru-502 324 (AP)

Introduction

The earth's climate is a dynamic process and it has always responded to changes in the cryosphere, hydrosphere, biosphere, and other interacting atmospheric galaxies. Although the effects of climate change on plant diseases was assessed in early nineties for New Zealand (Prestige and Pottinger 1990) and United Kingdom (Atkinson 1993). However, how the changing climate may influence the plant pathogens and the diseases they cause gained international importance only after Manning et al. (1995) first reviewed the impact of changing atmospheric CO_2, O_3 and UV-B on plant diseases. Soon after the presentation on "potential impact of climate change on plant–pathogen interactions" in the 7thInternational Congress of Plant Pathology in 1998 by Chakarborty et al. (2000), plant pathologists recognized that changes in climate will affect plant diseases together with other components of global change

i.e. anthropogenic processes such as air, water, and soil pollution, long-distance introduction of exotic species and urbanization (Gurr et al. 2011; Bradley et al. 2012; Matyssek et al.2012; Regniere 2012). Each year 10-16% of global harvest (Strange and Scott, 2005; Oerke 2006) is lost to plant diseases costing US$ 220 billion, with the emerging climate change scenarios the losses caused by plant disease are expected to be increasing by 3-4 folds.

To guide government policy and industry strategic decision–making, there is need to assess impacts of climate change on disease induced losses in food crop yields (Gregory et al. 2009). In a world where more than one billion people currently do not have enough to eat (Anon 2009), more work is needed to understand the impact of climate change adaptation procedures available to decrease predicted disease-induced losses in crop yields.In this article,though the focus is on plant pathosystemsit also can be argued for invertebrate pests.

Need

The well-known interaction between host × pathogen ×environment for plant disease epidemic development and weather based disease management strategies have been routinely exploited by plant pathologists. However, the impact of inter annual climatic variation resulting in the abundance of pathogen populations and realistic assessment of climatic change impacts on host-pathogen interactions are still scarce and there are only handful of FACE and OTC studies.

Climate change predictions, point to a warmer world with in the next 50 years, a trend that is increasingly being supported by 'ground-truth'. Climate change threatens to increase crop losses, increase in the number of people facing malnutrition, and changing the development patterns of plant diseases. Agriculture production of rainfed regions, which constitute about 65% of the area under cultivation and account for about 40-45% of the total production in India, varies a great deal from year to year. Therefore in order to sustain and enhance the production of the

rainfed crops, it is necessary to use the knowledge of climate variability to tailor the innovative cropping patterns and the disease management practices for location specific agro-climate zone.

It is well established that temperature, moisture and greenhouse gases are the major elements of climate change. Current estimates of changes in climate indicate an increase in global mean annual temperatures of 1ºC by 2025 and 3ºC by the 2100. Variability in rainfall pattern and intensity is expected to be high. Greenhouse gases (CO_2 and O_3) would result inincrease in global precipitation of 2 ± 0.5ºC per 1ºC warming. Overall, changes in these elements will result in i) warmer and more frequent hot days and nights ii) erratic rainfall distribution pattern leading to drought or high precipitation and iii) drying of rainfed tropics (specifically semi-arid tropics) in Asia and Africa. Temperature increaseassociated with climatic changes could result in following changes in plant diseases:

- Extension of geographical range of pathogens
- Changes in population growth ratesof pathogens
- Changes in relative abundance and effectiveness of biocontrol agents
- Changes in pathogen×host×environment interactions
- Loss of resistance in cultivars containing temperature-sensitive genes
- Emergence of new diseases/and pathogen forms
- Increased risk of invasion by migrant diseases
- Reduced efficacy of integrated disease management practices

These changes will have major implications for food and nutritional security, particularly in the developing countries of the dry-tropics, where the need to increase and sustain food production is most urgent. In this commentary an attempt has been made to introduce climate change to plant pathologists, update knowledge on its potential impacts on host–pathogen interactions, critically review progress, and initiatives taken by ICRISATon research needs to better manage legume (pulse) diseases under a changing climateas a case-study.It is sincerely hoped that this effort may sensitize the pathologists and researchers to initiate location specific multidisciplinary researchto device sustainable management options ofplant diseases as impacted by climate change in India.

Current Knowledge

The current knowledge on the main potential effects of climate change on plant pathosystems has been recently summarized by Pautasso et al. (2012). Their overview suggests that maintaining plant health across diversified environments is a key requirement for climate change mitigation as well as the conservation of biodiversity and provisions of ecosystem services under global change. Environmental influences on plant diseases have always been considered by plant pathologists: the classic disease triangle emphasizes the interactions between plant hosts, pathogen and environment in causing disease (Garrett et al. 2011; Grulke 2011). Climate change is one of the many ways in which the environment can move in long term from disease–

suppressive to disease–conducive or vice versa (Perkins et al.2011). Therefore Plant diseases could be used as indicators of climate change (Garrett 2009). There is a wide spread evidence that seasonal shifts in the current CO_2concentrations (180-300 ppm) measured from ice core of 650,000 years will exceed to 400 ppm in few years. The increase in $Co_2$and other gases already resulted in an increase in temperature by 0.6-0.7^oC over the last century (Walther et al. 2002) consequently certain regions are experiencing shorter and warmer winters (Quarles 2007). It is assumed that by the end of 21st century the global temperature will increase by + 2 to 4^oC (Milad et al. 2011). The increase in temperatures will affect the metabolite rates of several crop species and may make them vulnerable to existing or emerging pathogens and their forms. Also forecasted increase in extreme weather events such as floods, droughts, wind, rains and hails etc. will directly or indirectly impact plant health and disease epidemics.Recently Savary et al. (2012) highlighted theefforts of international phytopathologicalresearchtackling the effects of climate changes on plant diseases in the developing worldand suggested location and crop-pathogen specific entry points to address this issue.

Climate Change Research at ICRISAT

Climate change is no longer a 'myth' and it needs an interdisciplinary approach to understand the impacts and to develop mitigation strategy in particular reference to the Semi-Arid Environments globally and specifically to rainfed dryland farming in India. Climate research has been a top priority in developed countries like USA, Australia and European countries for several decades in order to develop strategies to minimize the impact of climate change. This is also an integral part of the strategic planning of top universities and research institutions in the world. India being a fast growing economy is emerging as major player in climate research in recent times. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), is a center of excellence in research on rainfed dryland agriculture, and has a diverse group of researchers actively pursuing research on effect of climate change on emerging plant diseases and insect-pests, and their effect on crop production. Sustainable crop production is the key issue for food security and economic growth.

To mitigate the risks of climate change, ICRISAT has developed climate ready-adapted products/cultivars of its mandate crops. For example, in chickpea it has developed wilt disease resistant cultivars combining drought tolerance in varieties such as ICCV 96029 [super early (75-80 days), ICCV 10 extra early (85-90 days), and KAK 2 early (90-95 days). These chickpea varieties are widely grown in farmers' fields in drought prone areas. ICRISAT plant pathologists and entomologist developed protocols to study biology and ecology of insect-pests and pathogens. They are also studying the host plant × pest × environment interactions, identifying biochemical responsible for pest resistance, molecular markers for pest resistance, pest variability, biochemical mechanisms of insect and host interactions, pest forecasting models, etc.

DST-ICRISAT Center of Excellence on Climate Change Research for Plant Protection

The Center of Excellence on Climate Change Research for Plant Protection (CoE-CCRPP) initiated at ICRISAT center at Patancheru Andhra Pradesh, to focus on impact of climate change on disease and insect-pest problems of rainfed dry land crops. In the first phase (2011-2014) basic studies to understand the effect of climate change variables on the diseases and insect-pests of chickpea and pigeonpea will be investigated. The project is supported by the Department of Science and Technology Climate Change Program. The primary aim of this project is to understand the effects of climate change on the relative abundance and diversity of insect-pests and pathogens across geographical regions, pathogen/pest × host plant × environment interactions, and its influence on insect-pest and diseases incidence and extent of losses due to diseases and pests. The major outcomes of this project will be the development of methodologies that will be required to quantify the information on emerging pest problems, their geographical distribution, and severity and damage, effect of climatic changes on expression of resistance to insect-pests and pathogens, select varieties that are resistant to diseases and insect-pests across environments, and reduce pesticide application for a safer environment. The information on pest × host × environment interactions will be useful to scientists in India, who can use the standardized techniques for phenotyping for pest resistance to identify and develop pest resistant cultivars for genetic management of emerging and or anticipated diseases and insect-pest problems in India. The information will be useful to research planners, policy makers, scientists, and farmers for sustainable crop protection in India. The outcomes of this project will have a major bearing on pest mitigation strategies in an environment friendly manner for sustainable production of grain legumes and increasing food security in dry land areas –the region most vulnerable to climate change.

Climate Change and Legumes Diseases R&D &ICRISAT

In the last one decade the disease scenario of chickpea and pigeonpea has changed drastically consequently, dry root rot (*Rhizoctoniabataticola*) of chickpea and Phytophthora blight (*Phytophthoradrechsleri*f.sp.*cajani*) of pigeonpea have emerged has potential threat to the production of these pulses in India (Pande and Sharma 2010). ICRISAT has initiated research on the impact of climate change on these diseases. In general models addressing legumes diseases in the tropics have not so far emphasized the effects of climate and global change. However, weather-based models to predict the development of Ascochyta blight and Botrytis gray mold in chickpea have been developed to provide sounder bases for fungicide use (Pande et al. 2005).

Increased heat and drought stress and monsoon shifts in South Asia tend to push legume production toward more marginal lands, where management options are fewer.Climate change alters the spectrum of diseases in terms of pathogen distribution and virulence, and appears associated with emergence of new pathotypes. For example, with increased temperature and more frequent moisture stress, Rhizoctonoa blight is becoming more intense in tropical –humid areas, while viruses and rusts dominate in worm but dry zones.Data collected in India from 2000 to

2010 show higher risk of dry root rot in chickpea varieties that are resistant to Fusarium wilt in years when temperature exceed 33^0C (Pande et al. 2010; Sharma 2010 et al.).This is consistent with green house experiments where different soil moisture levels and temperatures manipulated, showing that *R. bataticola*infected chickpea plants caused dry root rot faster at 35^0C with soil moisture level less than or equal to 60% (Sharma et al 2010).By contrast, cooler temperatures and wetter conditions are associated with increased incidence of stem rot (*Sclerotiniasclerotiorum*) on soybean (Workneh et al.2000), blights in chickpea (Pande et al.2005), and anthracnose (*Colletotrichum*spp.) in stylosanthes(Pengga et al.2004). Recently, studies indicated that the epidemic of Phytophthora blight of pigeonpea (*P.drechsleri*f.sp.*cajani*) in India over the last decade can be attributed to high intermittent rainfall(>300 mm), within a week during the crop season (Pande et al.2010; Sharma et al.2006).

GAP in Knowledge

It is critical that there should be a progress toward pro-poor, environmentally neutral, host plant resistances, as well as toward drought tolerance in crops especially grown in dry land tropics such as chickpea, beans, and cowpea etc. combined with systems-adapted integrated disease management technologies. In this context and because of the close interaction between global change and climate change, far too little research has addressed the effects of the latter on crop health.

Global change may affect crop health in quite different ways depending on the type of disease considered. Though there have been so many new methods available for plant pathologists to analyze data. However, the availability of ground truth data on crop health is a serious issue; the collection of system-based, holistic data remains a keystone towards progress to understand and manage constantly evolving pathosystems.

There is a need to create facilities, device methodologies, and develop collaborative research activities to understand the impact of climate change variables on crop health and plant diseases. Several available tools and methodologies such as simulating modeling, geographic information systems, mapping, technology targeting for efficiently implementing disease management tools as global change and climate change unfold. Actual measurement of disease in the field, their proper recording and processing is required for effective disease management as it depends on these combinations of resources, methods, and disciplines.

The topic of climate change and plant diseases has not yet sparked widespread interest among plant pathologists. This may be partly because of the well understood genetic basis of host-pathogen-specificity, where many of the crop disease management options are based on host plant resistance. However, realistic assessments of climate change impacts on host-pathogen interactions are still scarce and there are only handfuls of FACE studies. Despite being interesting from a pathogen life-cycle point of view, realistic effects of high CO_2 need to be considered in the context of rising temperatures and other changes projected under changing climate. New FACE

facility fostering multidisciplinary research on climate change in pest and diseases in crop cropping systems should be a priority in India.

REFERENCES

- Ainsworth EA, Long SP, 2005. What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. *New Phytologist***165**, 351–72.
- Anonymous, 2008a.*Food Matters Towards a Strategy for the 21st Century*. http://www.cabinetoffice.gov.uk/media/cabinetoffice/strategy/assets/food/food_matters_es.pdf
- Atkinson D (1993) 'Global climate change, its implication for crop protection.' (British Crop Protection Council Monograph No 56. BCPC, Surrey, UK)
- Baker, R.H.A., Sansford, C.E., Jarvis, C.H., Cannon, R. J.C., MacLeod, A., & Walters, K.F.A (2000). The role of climatic mapping in predicting the potential geographical distribution of non-indigenous pests under current and future climates.*Agriculture, Ecosystems & Environment*, 82, 57-71. Doi: 10.1016/S0167-8809(00)00216-4.
- Bradley, B. A., Blumenthal, D. M., Early, R., Grosholz, E. D., Lawler, J. J., Miller, L. P., et al. (2012). Global change, global trade, and the next wave of plant invasions.Frontiers in Ecology and the Environment, (in press).Doi:10.1890/110145
- Cerri, C. E. P., Sparovek, G., Bernous, M., Easterling, W. E., Melilo, J. M., &Cerri C. C. (2007). Tropical agriculture and global warming: impacts and mitigation options. *Scientia Agricola, 64,* 83-99.
- Chakraborty S, Newton AC (2011) Climate change, plant diseases and food security: anoverview *Plant Pathology***60**, 2–14
- Chakraborty S, Tiedemann AV, Teng PS (2000b) Climate change: potential impact on plant diseases. *Environmental Pollution (Barking, Essex: 1987)* **108,** 317-326. Doi: 10.1016/S0269-7491(99)00210-9
- Chakraborty, S., Luck, J., Hollaway, G., Freeman, A., Norton, R., Garrett, K. A., et al (2008). Impacts of global change on diseases of agricultural crops and forest trees. *CAB Reviews,3,* 054. Doi:10.1079/PAVSNNR20083054.
- Coakley SM (1995) Biospheric change: will it matter in plant pathology? *Canadian Journal of Plant Pathology***17**, 147-153
- Coakley SM, Scherm H (1996) Plant disease in a changing global environment. *Aspects of Applied Biology***45**, 227-237.
- Coakley SM, Scherm H, Chakraborty S (1999) Climate change and plant disease management.*Annual Review of Phytopathology***37**, 399-426. Doi: 10.1146/ annurev.phyto.37.1.399
- Fabre, B., Piou, D., Desprez-Loustau, M.-L., &Marcais, B. (2011) Can the emergence of pine *Diplodia* shoot blight in France be explained by changes in pathogen pressure linked to climate change? *Global Change Biology*, *17,* 3218-3227. Doi: 10.1111/j. 1365-2486.2011.02428.x.
- Garrett, K. A., Forbes, G. A., Sarvary, S., Skelsey, P., Sparks, A.H., Valdivia, C., et al. (2011). Complexity in climate change impacts: an analytical framework for effects mediated by plant disease. *Plant Pathology*, 60, 15-30. Doi: 101111/j.1365-3059.2010.02409.
- Garrett, K. A., Nita, M., De Wolf, E. D., Gomez, L., & Sparks, A. H., (2009). Plant pathogens as indicators of climate change. In T. Letcher (Ed.,), *Climate change: observed impacts on planet Earth* (pp. 425-437).Dordrecht: Elsevier.
- Gregory PJ, Johnson SN, Newton AC, Ingram JSI, 2009.Integrating pests and pathogens into the climate change/food security debate.*Journal of Experimental Botany***60**, 2827-38
- Grulke, N. E. (2011). The nexus of host and pathogen phenology: understanding the disease triangle with climate change*, New Phytologist*, 189, 8-11. Doi:10.111/j.1469-

8137.2010.03568.

- Gurr, S., Samalova, M., & Fisher, M. (2011). The rise and rise of emerging infectious fungi challenges food security and ecosystem health. *Fungal Biology Reviews*, 25, 181-188. Doi: 10.1016/j.fbr.2011.10.004.
- Jeger, M. J., &Pautasso, M. (2008).Plant disease and global change- the importance of long-term data sets.*New Phytologist*, 177, 8-11. Doi:10.111/j.1469-8137.2007.02132.x.
- Körner, C., & Basler, D. (2010).Phenology under global warming.*Science*, 327, 1461-1462. doi:10.1126/science.1186473.
- Luck J, SpackmanM, Freeman A et al., 2011. Climate change and diseases of food crops.*Plant Pathology***60**, 113–21.
- Manning WJ, Tiedemann AV, 1995. Climate-change – potential effects of increased atmospheric carbon-dioxide (CO_2), ozone (O_3), and ultraviolet-B (UV-B) radiation on plant-diseases. *Environmental Pollution***88**, 219–45.
- Matesanz, S., Gianoli, E., &Valladares, F. (2010).Global change and the evolution of phenotypic plasticity in plants.*Annals of the* New *York Academy of Sciences, 1206,* 35-55*.* Doi:10.1111/j.1749-6632.2010.05704.x.
- Matyssek, R.,Wieser, G., Calfapietra, C., deVries,W.,Dizengremel, P., Ernst, D., et al. (2012). Forests under climate change and air pollution: gaps in understanding and future directions for research.Environmental Pollution, 160, 57–65. Doi:10.1016/j. envpol.2011.07.007.
- Milad, M., Schaich, H., Burgi, M., &Konold, W. (2011). Climate change and nature conservation in Central European forests: a review of consequences, concepts and challenges. *Forest Ecology and Management, 261,* 829-843. Doi 10.1016/j.foreco.2010.10.0.38.
- Oerke EC, Dehne HW, Schonbeck F, Weber A (1994) 'Crop production and crop protection, Estimated losses in major food and cash crops.' (Elsevier: Amsterdam)
- Oerke, E.-C.(2006). Crop losses to pests. Journal of Agricultural Sciences, 144, 31–43.
- Pande, S., and Shanna, M. 2010. Climate change: Potential impact on chickpea and pigeonpea diseases in the rainfed semi-arid tropics (SAT). In: 5th International Food Legumes Research Conference (IFLRC V) and 7th European Conference on Grain Legumes (AEP VII) April 26-30, 2010, Antalya, Turkey.
- Pande, S., Desai, S., and Shanna, M. 2010. Impact of climate change on rainfed crop diseases: Current status and future research needs. Pages 55- 59 in: National Symposium on Climate Change and Rainfed Agriculture, February 18-20, 2010. Indian Society of Dryland Agriculture, Central Research Institute for Dryland Agriculture, Hyderabad, India.
- Pande, S., Stevenson, P. C., Rao, J. N., Neupane, R. K., Grzywacz, D., Bourai, V. A.,and Kishore, G. K. 2005. Reviving chickpea production in Nepal through integrated crop management, with emphasis on Botrytis gray mold.Plant Disease. 89:1252-1262.
- Pangga, I. B., Chakraborty, S., and Yates, D. 2004. Canopy size and induced resistance in *Stylosanthesscabra*determine anthracnose severity at high CO_2, Phytopathology 94:221-227.
- Pautasso, M. (2012). Observed impacts of climate change on terrestrial birds in Europe: an overview. Italian Journal of Zoology, (in press).Doi:10.1080/11250003.2011.627381
- Perkins, L. B., Leger, E. A., & Nowak, R. S (2011). Invasion triangle: an organizational framework for species invasion. *Ecology & Evolution, 1,* 610-625. Doi:10.1002/ece3.47.
- Prestidge RA, Pottinger RP (1990) 'The Impact of Climate Change on Pests, Diseases, Weeds and Beneficial Organisms Present in New Zealand Agricultural and Horticultural Systems.' (MAF Technology, Ruakura Agricultural Centre: Hamilton, New Zealand)
- Quarles, W. (2007). Global warming means more pests. *The IPM practitioner*, *29* (9/10), 1-8.

- Régnière, J. (2012). Invasive species, climate change and forest health. In T. Schlichter& L. Montes (Eds.), Forests in development: a vital balance (pp. 27–37). Berlin: Springer. Doi:10.1007/978-94-007-2576-8-3.
- S. Savary, F. Horgan, L. Willocquet, K.L. Heong. A review of principles for sustainable pest management in rice.Crop Protection 32 (2012) 54e63.
- Sharma, M., Mangala, U. N., Krishnamurthy, M., Vadez, V., and Pande, S. 2010.Drought and dry root of chickpea.In: 5th International Food Legumes Research Conference (IFLRC V) & 7th European Conference on Grain Legumes (AEPVII) April 26-30, 2010, Antalya, Turkey.
- Sharma, M., Pande, S., Pathak, M., Narayana Rao, J., Anil Kumar, P., Madhusudun Reddy, D., Benagi, D., Mahalinga, D. M., Zhote, K. K., Karanjkar, P. N., and Eksinshe, B. S. 2006.Prevalence of Phytophthora blight of pigeonpea in the Deccan Plateau. J. Plant Pathol. 22:309-313.
- Strange, R.N.; Scott, P.R. Plant disease: A threat to global food security. **Annual Review of Phytopathology,** v.43, p.83- 116, 2005.
- Walther, G.-R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J. C., et al. (2002). Ecological responses to recent climate change. *Nature 416,389-395*. Doi:10.1038/416389a.
- Workneh, F., and Yang, X. B. 2000. Prevalence of *Sclerotinia*stem rot of soybeans in the north-central United States in relation to tillage, climate and latitudinal positions. Phytopathology 90:1375-1382.

Irrigation Techniques for Protected Cultivation

P. K. Singh
Department of Irrigation and Drainage Engineering, G.B.P.U.A.&T., Pantnagar- 263 145 (UK)

Plants depend on water and within the protected structure with no rainfall to supply it naturally and the added warmth to make the soil dry out more quickly. However, near zero wind velocity under many protected environments such as polyhouses, poly tunnels, low tunnels etc., the water requirement of many crops decreases significantly (Rana *et al*, 2010). Traditional watering-cans are, of course, the simplest solution to the problem. They are particularly useful in providing very specific, targeted watering for individual plants, particularly if they are being grown in pots or containers. However, as a means of achieving mass watering, they are far too labour-intensive to be practical for anything other than the smallest of greenhouses. Many gardeners are inclined to try to overcome the limitations of the watering can by using a hosepipe instead, but this approach itself has its problems – chiefly in terms of achieving the delivery of water where it is really needed, rather than on the leaves and soil surface. The traditional method of irrigation as in case of open filed condition creates lot of disease under protected environment because of the increased level of relative humidity along with increased temperature. Therefore, the appropriate irrigation techniques having the characteristics of frequent application of water in small quantity as per crop need at right location in right manner is essential for obtaining the maximum benefit of protected cultivation. Micro irrigation has ability to provide right amount of water, at right time, at right place in right manner. Similarly, nutrients may also be applied precisely along with irrigation water using the fertigation device along micro irrigation. In this way significant amount of two important agricultural inputs (water and nutrients) could be saved significantly besides controlling the environmental (non- point source / agricultural) pollution. Further, it has the potential to increases crop yield. There is an additional positive environmental impact from precision irrigation in that farm runoff, a major source of water pollution, can be reduced. The major limitations associated with precision irrigation are high initial cost; operation and maintenance need skilled work force.

1. Protected Cultivation

Protected cultivation practices can be defined as a cropping technique wherein the micro environment surrounding the plant body is controlled partially/ fully as per plant need during their period of growth to maximize the yield and resource saving. With the advancement in agriculture various types of protected cultivation practices suitable for a specific type of agro-climatic zone have emerged. Among these protective cultivation practices, green house/poly house cum rain shelter is useful for the hill zones. The green house is generally covered by transparent or translucent material such as glass or plastic. The green house covered with simple plastic sheet is termed as poly house. The green house generally reflects back about 43% of the net solar radiation incident upon it allowing the transmittance of the "photosynthetically active solar

radiation" in the range of 400-700 Nm wave length. The sunlight admitted to the protected environment is absorbed by the crops, floor, and other objects. These objects in turn emit long wave thermal radiation in the infra red region for which the glazing material has lower transparency. As a result the solar energy remains trapped in the protected environment, thus raising its temperature. This phenomenon is called the "Green house Effect". This condition of natural rise in green house air temperature is utilized in the cold regions to grow crops successfully. However, during the summer season due to the above stated phenomenon ventilation and cooling is required to maintain the temperature inside the structure well below 35°C. The ventilation system can be natural or a forced one. In the forced system fans are used which draw out 7- 9m^3 of air/sec/ unit of power consumed and are able to provide 2 air changes / minute.

2. Why Protected Cultivation?

- ⇒ The vegetables / any other produce harvested from the protected cultivation have better quality in terms of the fruit size, per fruit weight, TSS, colour, texture and other quality parameters.
- ⇒ The productivity of the crop under protected cultivation increases manifold (2-10 times) as compared to conventional system.
- ⇒ Off-season cultivation of the vegetables/other crops is the most important aspect of protected cultivation. The winter season vegetable crops such as cauliflower, coriander, spinach etc can be grown during rainy season. Similarly, summer season vegetable crops are successfully grown during winter and the winter season leafy vegetable can be grown during summer.
- ⇒ Under protected environment the incidence of insect and disease are minimized due to its isolation from open field. Use of micro irrigation and off-season cultivation also minimizes the disease and insect incidence. Less infestation of insects and disease offer reduced use of pesticides.
- ⇒ The protected cultivation offers efficient use of two most precious resources land and water. Other inputs such as fertilizers, chemicals and labour are also efficiently utilized under such environment.
- ⇒ The year round cultivation of single / multiple crops with high quality produce and high productivity. The off-season cultivation of vegetable offers better market price and increased employment generation round year for the small and marginal farmers in hills and peri-urban areas.

3. Irrigation Techniques for Protected (Green House/Shade Net House and Walking /Low Tunnel) Cultivation

It is very difficult to obtain full benefit from protected cultivation without microirrigation and fertigation. An efficient irrigation system preferably microirrigation combined with fertigation system

must be an essential component of protected cultivation. Therefore, an irrigation system is essential for growing plants in a greenhouse. Plants rely on water to live and grow and because a greenhouse will not allow natural rainfall in, artificial means for irrigation become necessary. A variety of irrigation methods exist, and each method has benefits and drawbacks. Choosing the best irrigation method depends largely on the size of the protected structure and the types of plants growing inside. Often the most effective irrigation comes from a combination of methods.

3.1 Types of irrigation systems for nurseries

A plant nursery requires an irrigation system to water plants effectively and simultaneously. Creating a nursery to house your plants can involve a significant effort and commitment. Necessary decisions include selecting plant species, soil types and building materials. Also consider the amount of time and money available to invest in such a project. Nurserymen should think about which watering or irrigation system best suits their nursery type and size.

3.1.1 Overhead sprinkler irrigation systems

Nurserymen using overhead sprinklers typically have two options. The first option, rotary sprinkler heads, contain a rotating nozzle that sends a torrent of water over plants. The second option, stationary sprinkler heads, sends a rapid flow of water against a plate. The impact disrupts the steady stream of water, turning it into a continuous spray that waters plants.

Although overhead sprinkler systems are the most common option in nurseries, they are not very efficient. They require high pressure pumps that consume large quantities of energy. Overhead sprinklers also waste about 80 percent of the water emitted. In nurseries containing plants with large or broad leaves, these plants encourage water waste when leaves redirect water away from plant containers rather than into the soil. Some gardeners compensate for water loss by installing slanted plant beds that channel water into ponds where it can accumulate and be recycled back into the nursery, although this may also recycle bacteria, sodium, fertilizer or pathogens as well.

3.1.2 Microirrigation systems

Unlike overhead sprinklers, microirrigation systems are highly efficient and can function using low pressure. However, soil, algae and chemical fertilizers can clog emitters for which various types of filters are provided. Three types of microirrigation systems are used in nurseries. One type of microirrigation, known as the capillary mat system, uses tubes that carry water into a mat. The mat becomes saturated with water, providing containers sitting on top of the mat with a supply of water to soak up through plant root systems. Although capillary mat irrigation uses 60 percent less water than conventional overhead sprinkler systems, they can cause salt accumulation in the soil over long periods of time.

The second type of microirrigation system is known as a microsprayer, microsprinkler or spray stake system. Considered one of the most efficient nursery irrigation systems, microsprayers use a tube to carry water directly into the soil from a water source. Not only does this eliminate

water waste that is deflected off broad plant leaves, microsprayers carry water directly to the plant's root system. Although microsprayers cost more than overhead sprinklers when installed in small plants, they operate efficiently in larger plants with more foliage and heavier canopies.

The third type of microirrigation is known as the spaghetti tube system. This nursery irrigation method uses narrow tubes to bring water into the plant container. A miniature weight at one end of the tube ensures that it stays in the container. Water travels from one pore to another, through a capillary system. Consequently, gardeners must use a high quality, uniform soil for maximum efficiency. When using the spaghetti tube system, gardeners should keep soil moist at all times; dry soil will lead to poor water distribution.

3.1.3 Capillary sandbeds

Unlike sprinkler and microirrigation systems, capillary sandbeds do not involve any electricity. Containing wood panels, a plastic liner, sand, a small water reservoir, drainage pipe and valve, capillary sandbeds are built to slant slightly, allowing water released into the raised end to slowly travel to the lower end. Providing an even and continuous water supply, capillary sandbeds involve less maintenance. Plants grow evenly, relying less on fertilizer and pesticide. However, capillary sandbeds do attract weeds. Gardeners can purchase products to reduce the occurrence of weeds or they can remove them manually. Capillary sandbeds also have high installation costs.

3.2 Types of mist irrigation systems recommended in poly house

Overhead irrigation can produce constant humidity in poly-tunnels. A misting sprinkler system produces a very fine spray or mist over plants. Greenhouses, poly-houses and poly-tunnels can use either overhead or bench misting. The best type for your needs depends on what you are growing, the size of your poly house -- essentially plastic over a framework -- and on the growing conditions in your area.

3.2.1 Overhead systems

In overhead misting systems, lines or sprinklers are installed under the roof framework of your poly-house, and this "rain" water down onto your plants. This type of irrigation system is easy to automate and produces high humidity. This high humidity allows you to protect crops against frost damage. For the best coverage, space overhead sprinklers to around 50 to 60 percent of the wetting diameter of the sprinkler.

3.2.2 Bench misting

Bench misting uses a central line of sprinklers or hoops placed at or just above the level of your plants. Bench misting requires plants to be placed on raised benches, and these must be made of materials that are impervious to water, such as a metal. You can also use a self-contained misting bench, in which the bench is partially covered with a "roof." This allows you to have just a single misting bench in the poly-house, and a different watering system in the rest of the poly-house.

Benefits

Both types of misting system are well suited to plants that need to be kept moist, such as seedlings, and to reducing temperatures in a poly-house. Misting is commonly used for propagation and for growing tropical plants that require constant humidity. Some misting systems can also be used to spray fertilizers evenly and finely. Fertilizer applied this way is more easily absorbed into the plants than fertilizer applied on the soil. By allowing you to vary the humidity within the poly-house, mist systems also allow you to vary the temperature and control the growing conditions.

Drawbacks

It can be easy to over-water with either type of mist irrigation system. To prevent this, you can use a timer to turn the water on and off. Misting nozzles have very fine holes that can clog up if hard water is used. Misting also works best if poly-house is completely enclosed, as a breeze can disrupt the fine spray and cause areas to remain dry. Misting may not be suitable for all types of plants, so if poly-house contains many different types of plants, with different water tolerances, one may need to water each type of plant individually, or use individual benches, rather than use an overhead mist irrigation system.

3.3 Drip irrigation system

Drip irrigation is one of the most efficient methods of watering, typically operating at a 90 percent efficiency rate. Runoff and evaporation are at a reduced rate when compared to other irrigation systems such as sprinklers. In drip irrigation, tubes that have emitters run alongside the plants receiving irrigation. The water leaves the tubing through the emitters by slowly dripping into the soil at the root zone. This method of irrigation minimizes leaf, fruit and stem contact with water resulting in reduced plant disease. It reduces weed growth by keeping the area between plants dry. Irrigation through the drip method can be set to run automatically or controlled manually.

Drip watering is excellent way to water in greenhouses and tunnels as it keeps the humidity low leading to less pest and disease problems. Water is directed to exactly where it is needed either with an individual dripper, especially for pot grown plants, or inserted into a pipe for beds. Ideal for raised beds

3.4 Ebb and flood tables

Ebb and flood tables are frequently used in greenhouses where growers raise plants hydroponically. But an ebb and flood table may also be used for plants that the grower is growing traditionally. In an ebb and flood table, the plants are kept in a tray that has a hose nozzle at one end to admit water into the tray and a drain at the other end where the gardener can let water out of the tray. Plants that are kept in individual receptacles in the tray wick up water from the base of their containers. Gardeners who wish to recycle water and eliminate waste make use of ebb-and-flow systems for their greenhouses.

3.5 Hand watering

Hand watering is the most basic method of irrigation for a greenhouse. Watering cans or

hoses with nozzles allow you to tailor watering to the needs of individual plants. This is also the most labor-intensive method for plant irrigation and may not be effective for large greenhouses.

4. Irrigation Scheduling

4.1 Greenhouse drip irrigation scheduling

Availability and decreased quantity of water for agriculture highlights the objective of optimizing productivity, with adequate and efficient irrigation, that replenish the root zones soil water deficit and maximize the applied water that is stored in the rooted soil profile and used afterwards by the crop, in order to reach best yields (Castilla, 1990). As crop responds more to soil water level and irrigation regime than to method of irrigation, information developed for other irrigation methods is applicable to drip systems, in general.

Four basic questions must be answer in pursue precise irrigation scheduling

1) When to irrigate? (Frequency)

2) How much water to apply? The amount of water to be applied must replenish the evapotranspirated water, once corrected by the application efficiency (as far as the soil-water content variations are unimportant, due to the high frequency of drip irrigation). When saline waters are used, the applied water must cover the leaching requirements (Ayers *et al*, 1976; Doorembos *et al*, 1976; Stegman *et al*, 1980; Vermeiren *et al*, 1980). Other components of the water balance are normally unimportant in drip irrigated greenhouses (unless the rainfall penetrates inside, as it is the case in flat-roofed perforated plastic greenhouses).

3. Where to irrigate (point/line/ strip/disc source)

4. How to irrigate – drip (surface or subsurface) bubbler, micro sprinkler, mist etc.

4.2 Evapotranspiration (ET) in protected environment

Evaporation of water requires energy. The availability of energy depends on the microclimate of the protected environment, being the solar radiation the primary source of energy in the ET process. In an unheated greenhouse, the energy used in the ET process can reach 70% of incoming solar radiation (Hanan, 1990). The amount of ground area covered by the crop is the most relevant factor affecting ET. Evaporation (E) from the soil surface is high following an irrigation, but decreases rapidly as the soil surface dries. The transpiration (T) will increase with the rise of intercepted radiation (and subsequent increase of ground covered by the crop), while soil E will decrease (as the crop progressively shades the soil surface). Other energy sources (greenhouse heating hot air flow) can increase ET.

Crop evapotranspiration (ETc) or crop water requirements can be related with a reference value "reference evapotranspiration" (ETo) which is defined as "the rate of evapotranspiration from an extended surface of 8 to 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water". (Doorembos *et al*, 1976)

$$ET_c = K_c \times ET_o \quad \ldots (1)$$

The crop coefficient (Kc) is "the ratio between ET_c, and ET_o" and depends basically on the crop characteristics, the sowing or planting dates, the development rate of the crop, the length of the cycle, the climatic conditions and the irrigation frequency, especially at the beginning of the cycle (Doorembos *et al*, 1976).

In greenhouses, the class A pan evaporation method, as well as the radiation (FAO) and Priestley-Taylor methods, have been proposed as the more reliable for ET, estimation, for periods of several days (Castilla *et al*, 1990-B). The difficulty of an accurate measurement of the wind inside the greenhouse (Castilla *et al*, 1990-B) limits the use of the Penman method. The ease of management of the evaporation pan, without sophisticated equipment, is remarkable, but a proper pan placement is necessary.

The crop coefficient figures for different vegetable crops under greenhouses have been estimated (Castilla, 1989; Castilla *et al*, 1990-B; Martinez *et al*, 1990; Veschambre *et al*, 1980).
When using the class A pan method:

$ET_o = K_p \times E_o$

Kp = pan coefficient

E, = pan evaporation

$ET_c = Kc \times ETo = K_c \times K_p \times E_o = K \times E_o$ … (3)

Where $K = K_p \times K_c$ … (4)

Recent studies show that Kp inside the greenhouse is approximately 1.0 (Sirjacobs, 1986; Castilla, 1986; Castilla *et al*, 1990-B), higher than open-air values (Doorembos *et al*, 1979). The crop coefficient evolution and values for different vegetable crops are presented in table 1. Recent research in the Almeria area confirms the K values detailed in Table 1, pointing that Kp is around 0.8-0.9, but the quantified values of Kc are higher than those described in the literature(Doorembos *et al*, 1976), being the products of both coefficients (Kp xKc) similar to those indicated in Table 1.

Table 1: Crop coefficient values for different vegetable crops in a plastic green house in Almeria, using drip irrigation.

Days after sowing or transplanting	Tomato	Capsicum	Cucumber	Melon	Watermelon	Beans	Eggplant
1-15	0.25	0.20	0.25	0.20	0.20	0.25	0.20
16-30	0.50	0.30	0.60	0.30	0.30	0.50	0.35
31-45	0.65	0.40	0.80	0.40	0.40	0.70	0.55
46-60	0.90	0.55	1.00	0.55	0.50	0.90	0.70
61-75	1.10	0.70	1.10	0.70	0.65	1.00	0.90
76-90	1.20	0.90	1.10	0.90	0.80	1.10	1.10
91-105	1.20	1.10	0.90	1.00	1.00	1.00	1.05
106-120	1.10	1.10	0.85	1.10	1.00	0.90	0.95
121-135	1.00	1.00	-	1.10	0.90	-	0.85
136-150	0.95	0.90	-	1.00	-	-	0.80
151-165	0.85	0.70	-	-	-	-	0.80
166-180	0.80	0.60	-	-	-	-	0.80

181-195	0.80	0.50	-	-	-	-	0.80
196-210	0.80	0.50	-	-	-	-	0.80
211-225	-	0.60	-	-	-	-	0.80
226-240	-	0.70	-	-	-	-	0.60
241-255	-	0.80	-	-	-	-	0.60
TOT ET_c	318	322	156	349	290	146	393

The net irrigation requirements (IRn) must replenish the crop evapotranspirated water (ET,), as rainfall and other components of the water balance are normally unimportant in greenhouses in the Mediterranean area.

The gross irrigation requirements (IR) must increase the IRn, in order to compensate the irrigation efficiency and to leach salts.

$$IRg = \frac{IRn}{Ea(1-LR)} \quad \ldots (5)$$

Where Ea, = irrigation efficiency coefficient (smaller crop root zone to be used by the crop/applied water.

Ea=Ks x Eu … *(6)*

Ks is a coefficient (smaller than 1) which expresses the water storage efficiency of the soil (0.9 in sandy soils, 1.O in clay or loam soils).

Eu is a coefficient (smaller than 1) which reflects the uniformity of water application (a properly designed and well managed drip system should reach Eu values of 0.85-0.95). This coefficient should be measured for each system regularly (Vermeiren *et a1* 980).

LR: minimum amount of leaching needed to control salts with drip irrigation

$$LR = \frac{ECw}{2(maxECe)} \quad \ldots (7)$$

ECw: electrical conductivity of the irrigation water (dS/m)

ECe: maximum electrical conductivity (dS/m) of the soil saturation extract due to crop withdrawal of soil water to meet its evapotranspiration demand. Typical max ECe values are 12.5 in tomato, 10.0 in cucumber, 8.5 in pepper *6.5* in bean. Recent research shows that the leaching requirements could be lower than the indicated values (Stegman *et al*, 1980).

A study conducted at department of Irrigation and Drainage Engineering, GBPUA&T, Pantnagar showed that (Fig 2 to 5) the water requirement for capsicum varies from 0.90lpd/plant to 0.8519lpd/plant for open conditions, 0.067lpd/plant to 0.474lpd/plant for 35% shading conditions, 0.0675lpd/plant to 0.4605lpd/plant for 50% shading conditions and 0.052lpd/plant to 0.423lpd/plant for 75% shading condition (Fig 1). The water requirement for tomato varies from 0.090pd to .93lpd/plant for open conditions, 0.067lpd/plant to 0.63lpd/plant for 35% shading conditions, 0.067lpd/plant to 0.62lpd/plant for 50% shading conditions and 0.059lpd/plant to 0.46lpd/plant for 75% shading condition (Fig 2). The water requirement for cucumber varies from 0.051lpd/plant to 0.81lpd/plant for open conditions, 0.0385lpd/plant to 0.545lpd/plant for 35% shading conditions, 0.038lpd/plant to 0.529lpd/plant for 50% shading conditions and 0.030pd to

0.403lpd/plant for 75% shading condition (Fig 3).The water requirement for summer squash varies from 0.0945lpd/plant to 0.608lpd/plant for open conditions, 0.038lpd/plant to 0.409lpd/plant for 35% shading conditions, 0.0385lpd/plant to 0.397lpd/plant for 50% shading conditions and 0.030pd to 0.302lpd/plant for 75% shading condition (Fig 4) (Rana and Sah, 2010).

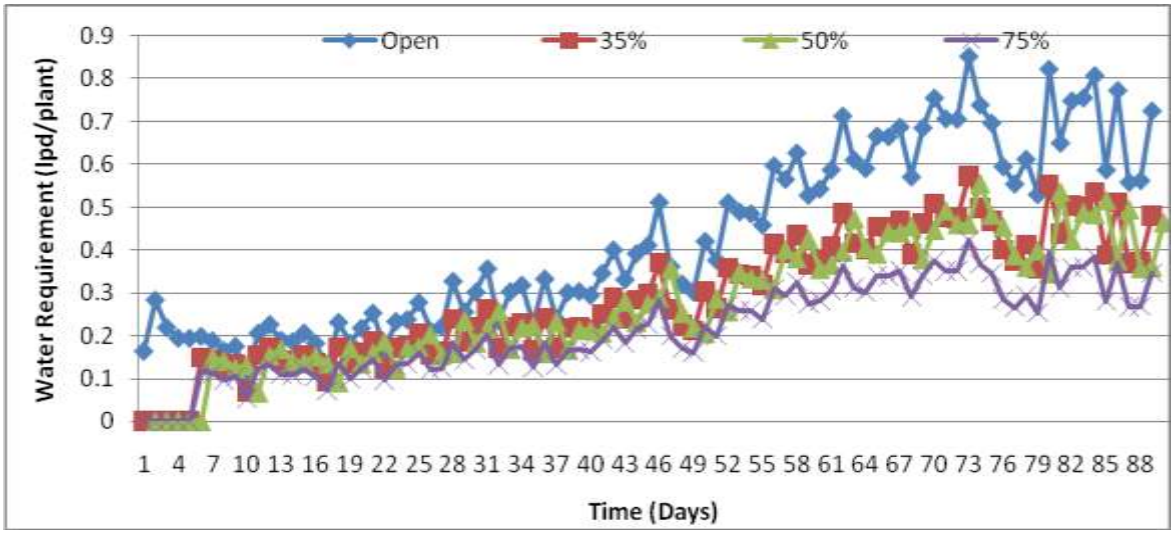


Fig 1: Water requirement of Capsicum under open field and shadenet

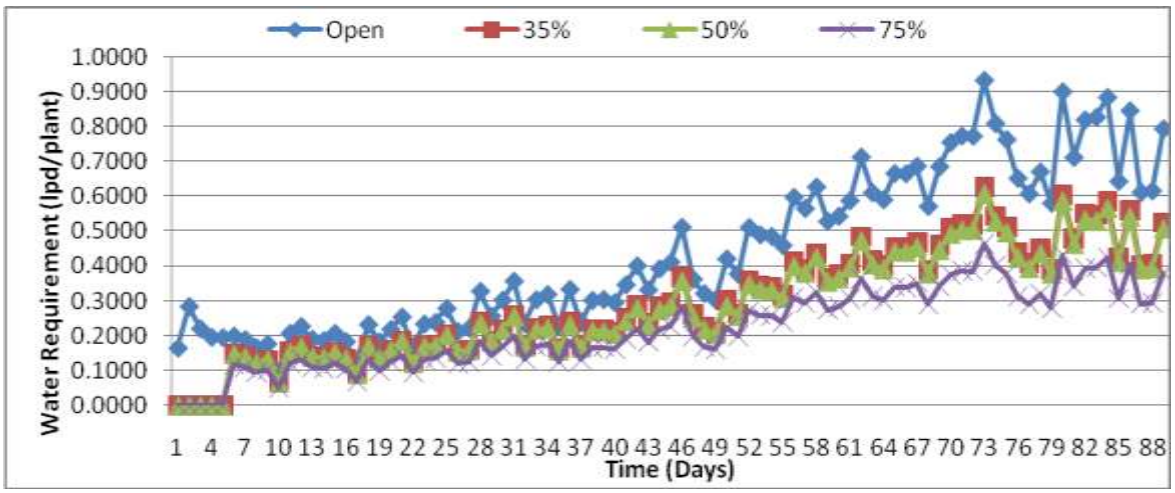


Figure 2: Water requirement of Tomato under open field and shadenet

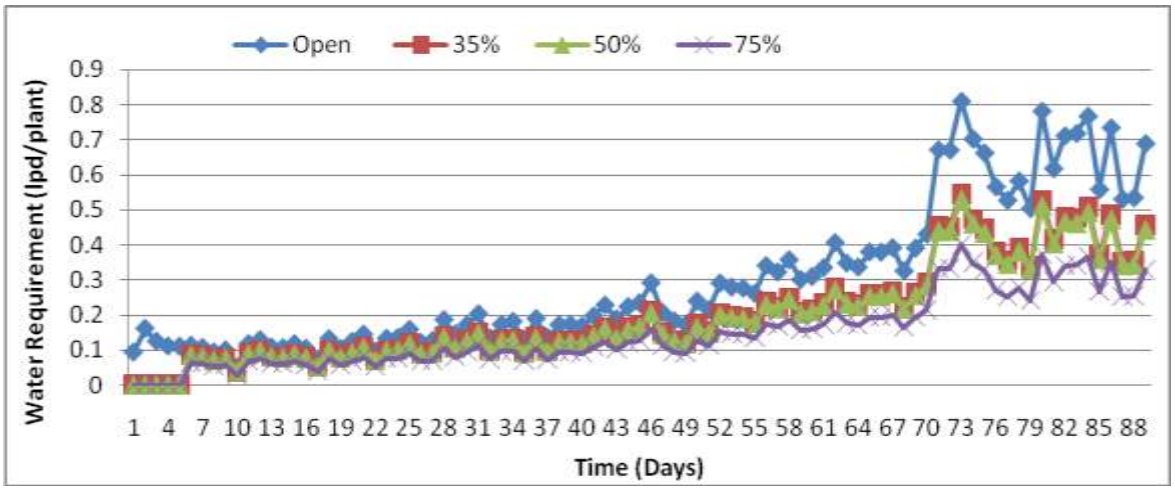


Figure 3: Water requirement of Cucumber under open field and shadenet

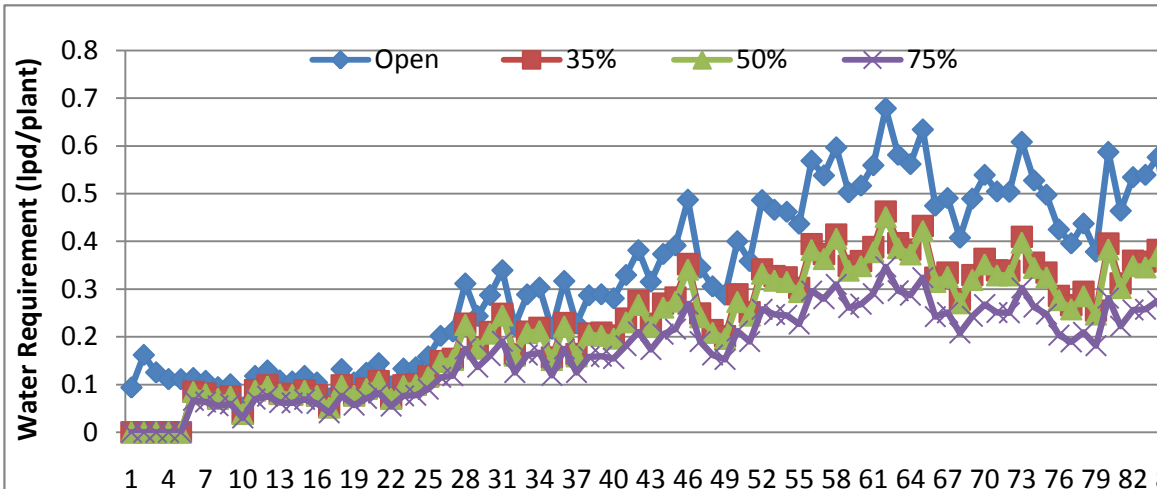


Figure 4: Water requirement of Summer Squash under open field and shadenet

4.3 Drip irrigation frequency

In conventional irrigation, soil water depletion must be maintained below certain thresholds (available soil water depletion) in order to avoid crop transpiration reductions, that can induce yield decrease. A proper irrigation frequency will avoid excessive depletion. In drip systems, good management will always be based on very high irrigation frequency, even several times each day (Villele, 1984), specially when using saline water, being the water storage role of the soil unimportant relative to conventional irrigation methods.

Different plant and soil parameters have been suggested to schedule the irrigation frequency. A wide range of plant based measurements more or less sophisticated (sap flow, stem diameter, water potential, plant temperature...) have been suggested to detect stress, using the plant as a biosensor. The leaf water potential method, reliable when used in conventional irrigation systems, is not practical in drip irrigated vegetable crops. Plant temperature based methods of water stress detection are more accurate in greenhouse than in open field (Stanghellini, 1993) but they must be developed and locally adapted. The crop water stress index, based on the higher temperature of the crop when suffering from water stress, has been suggested as a more reliable method, but it is not easy to use. The spatial variability of soil-water contents in drip-irrigated soils limits the interest of methods based on soil water content measurements ("available soil water depletion"). The soil water matrix potential measurement, in drip irrigated. soils, using tensiometers is a reliable way for monitoring soil water conditions in the wetted zone, in order to fix the irrigation frequency and to confirm the adequacy of the applied water amount. Two tensiometers, at least, should be placed in each observation point, installed at two depths, a few cm away from the emitter, depending on the soil water distribution and rooting patterns. Other methods for monitoring soil water potential, as gypsum blocks, need a good calibration depending on the composition of the soil solution and have not spreaded.

Wetting the soil profile with preplanting conventional irrigations (for salt leaching, soil

disinfection or other purposes) is useful to prevent possible drip-applied water deficits (Castilla *et al*, 1990 -A).

In soilless culture, the irrigation frequency must be several times per day, dividing the daily water requirements, according to the evaporative demand and the water storage characteristics of the substrate. In a -first approach, the evolution of solar radiation along the day (that determines primarily the evaporative demand) can be a guide to schedule the irrigations. Various automatic devices have been developed. Some of them are based in maintaining a minimum level of water in the substrate (i.e. using electrodes to activate the irrigation), while other automatic devices use a balance to replace the evapotranspirated water. The simplest method is to preprogram the irrigation time or volume; the conductivity of the drainage water is used to adjust the irrigation dosage and frequency.

5. Water Saving and Water Use Efficiency

Normally the greenhouse grower is not specially interested in water saving. The crude/little knowledge about the irrigation requirements among growers induce them to over irrigate. Proper information on the irrigation requirements, spreaded at the farm level, can help to overcome this lack of interest to reduce the water demand.

Different measures to save water and improve its use, at the farm level, include reducing the water requirements, increasing the water availability and raising the yields. The use of mulching (plastic sheet, sand, gravel,..) has been widely spreaded to limit the evaporation of the soil water and reduce ET. Subsurface drip irrigation can reach similar results. Various cultural practices affect the water demand. The use of transplants instead of direct seeding, multiple cropping, varying plant density, electing the cycles, pruning, trellising are effective, when properly managed, to save water or to increase the yield quantity and quality.

An adequate greenhouse environmental management can reduce the water demand, increase the crop yields and, therefore, improve the water use efficiency. Manipulating ventilation, misting, shading and carbon dioxide (CO_2) injecting are effective techniques for that purpose. (Boulard *et al*, 1991; Stanghellini, 1993; Castilla, 1994).

Tapping/Cropping the rainwater from the greenhouse roof is an easy way to increase the water resources especially relevant for its excellent quality. Another way is to make a better use of the water stored in the soil profile ; pulling up the crop immediately after the yield is over (avoiding the soil water exhaustion with no agronomic. interest) or managing rationally the complementary irrigations (as those used for soil disinfection) in the watering schedule. Slight deficit-irrigations have been recommended as they do not affect yield in tomato (Villele, 1984), though they can reduce total biomass.

When the soil profile is well-wetted before planting, slight deficit irrigation does not influence yield in greenhouse tomatoes and melons (Castilla *et al*, 1990-C). Condensing the water from the saturated air can also help to reduce the fungal disease incidence, but economics are not

clear (Boulard *et al,* 1989).

Maximizing the uniformity of water application is one of the easier ways to save water, at the farm level, too frequently forgotten. The evaluation of the emission uniformity of the drip system should be done periodically. In a study conducted by Orgaz *et al,* 1986, thirty drip systems were evaluated in the Almeria greenhouse industry; the results showed that the uniformity coefficient (UC) varied between 51 and 93%, the average UC being 76%. And only 4% of the systems had excellent uniformity while UC was unacceptable in 20% of them. B) Applied water was considered excessive in 50% of the farms studied.

Protected cultivation improves the water productivity due to the ET reduction and larger outputs of protected growing (Stanghellini, 1993). Drip irrigation also increases the water productivity, relative to conventional irrigation in greenhouses. The 20 kg of yield per cubic meter of applied water quantified in open field tomato growing in the Mediterranean area, can be increased to 33 kg per m^3 in unheated plastic house (Castilla *et al*, 1990-C), far from the 65- kg per m^3 obtained in sophisticated greenhouses, with soilless culture and very long cycles, in Holland (Stanghellini, 1994).

The use of recirculating soilless culture can improve the water productivity but the poor quality of water, the high cost of the equipment (for quantifying the ion concentration and disinfecting the re circulating solution) and the absence of proper information, at the farm level, limits its use. Table 2 summarizes the economic yields per cubic meter of applied water (water productivity) in commercial plastic houses in the Almeria area (Spain). In some cases, the agronomic water use efficiency (water productivity) is lower in soilless culture than in soil-grown crops (Table 2), showing the need of applied research on this subject.

Table 2: Water productivity (economic yield, in kg, per m^3 of applied water) of various drip irrigated crops, evaluated in commercial unheated greenhouses in Almeria (Spain), in conventional soil and soilless cultures, in the autumn and spring cycle (up) and long season cycle (down)

	Autumn		Spring	
	Soil	**Soilless**	**Soil**	**Soilless**
Short Cycle Crops				
Squash	41.0	-	-	-
Green bean	15.0	18.5	20.5	22.0
Cucumber	27.5	43.5	-	-
Melon	-	-	22.5	19.5
Watermelon	-	-	30.5	
Long Cycle Crops				
Tomato	34.0	29.0		
Pepper	13.5	-		
eggplant	18.0	-		

A study conducted at PFDC, GBPUA&T, Pantnagar, India on tensiometer based drip irrigation and fertigation scheduling on capsicum under polyhouse. In Double Span Naturally Ventilated Polyhouse (DS NVPH), the water use efficiency was observed maximum in the

treatment irrigated at 50-70kPa soil moisture tension and 75% of normal fertilizer doses (I_3F_1) by 281.31 % higher as compared to the control treatment. The water use efficiency was increased higher in the treatment by 248.05 % as compared to the control treatment in WT NVPH. The water productivity of treatment irrigated at 50-70 kPa soil moisture tension and normal fertilizer doses (I_3F_2) was observed to be decreased by -72.43 under DS NVPH and -71.45 % under WT NVPH in treatment irrigated at 50-70kPa soil moisture tension and 75% of normal fertilizer doses (I_3F_1) as compared to control treatment (Table3).

Table 3: Effect of tensiometer based irrigation and fertigation on capsicum yield (kg/m^2), water use efficiency and water productivity in DS NVPH and WT NVPH

Treatment	DS NVPH			WT NVPH		
	Yield (kg/m^2)	WUE (kg/m^3)	Water productivity (liter/kg)	Yield (kg/m^2)	WUE (kg/m^3)	Water productivity (liter/kg)
I_1F_1	12.00	48.18	20.76	12.35	40.73	24.60
I_1F_2	12.34	49.55	20.33	13.81	45.53	22.01
I_2F_1	10.92	62.74	17.07	11.67	81.37	12.94
I_2F_2	12.28	70.55	14.40	13.49	70.66	14.20
I_3F_1	13.14	100.59	10.15	13.04	90.91	11.00
I_3F_2	12.54	96.00	10.47	11.94	83.19	12.08
C	8.52	26.38	37.98	9.56	26.12	38.53
CD (P=0.05)	NS	20.47	4.56	NS	17.51	4.12

I_1: Drip irrigation at 20-30 kPa soil moisture tension; I_2: Drip irrigation at 30-50 kPa soil moisture tension; I_3: Drip irrigation at 50-70 kPa soil moisture tension; F_1: 75% of recommended fertilizer doses; F_2: 100% of recommended fertilizer doses

6. Automated Watering

Watering a large number of plants in a well-stocked greenhouse can be a major task, especially if it is to be done by hand. However, there are alternative approaches available, including seep hoses, drip irrigation, misters and sprinkler systems, which make the job much easier. Many of these systems can be automated to varying degrees, using modern timers or controllers, which range from the cheap and simple to the very sophisticated – with a price tag to match! Water timers, for instance, fit between the irrigation hose and the tap and can be set to allow watering to take place at specific times of the day and for a given period, allowing you to water at night to avoid evaporation, for example, without having to be there yourself. These relatively simple devices are also invaluable if you are out all day or when you go away, keeping the soil nicely moist in your absence. More complex water controllers can take the automation even further, measuring soil moisture and watering accordingly to keep the growing conditions at their optimum.

7. Water Quality Management for Green House Irrigation

A dependable irrigation water supply is a vital component of any greenhouse growing operation. In the past, the quality of the water source was not a cultural issue considered by growers. The water source may contain essential nutrients such as iron or nitrate in high enough

concentrations to justify a reduction in levels applied through a fertility program. Water may also contain harmful impurities that require corrective procedures. Water quality can be a deciding factor when choosing among sites for establishing a new greenhouse business or, where the opportunity exists, to choose among two or more water sources at a particular site. Growers should have their irrigation water tested by a university or reliable private laboratory any time a new water source is established, whether it be from a well, river, pond, or municipal system. Afterward, test the water at least twice per year or often enough to establish how much variability there is in water quality over time. One good approach is to take one test during a wet period and another during a dry period because high rainfall can dilute water impurities and drought can concentrate water impurities. Once a water quality pattern has been established, yearly testing is usually sufficient. The recommended water quality parameters have been presented in Table 4 suitable for protected cultivation.

Table 4: Recommended upper limits of chemical factors in Irrigation water for greenhouse crop production

Quality parameters		**Recommended limit of factors**
pH		5.4 to 6.8
Alkalinity		150 ppm $CaCo_3$ (3 meq/L)
	Bicarbonates	122 ppm (2 meq/L)
	Hardness (Ca+Mg)	150ppm $CaCo_3$ (3meq/L)
Electrical Conductivity		
	Plug grown seedlings	0.75 mmhos/cm
	General production	1.5 mmhos/cm
Total Dissolved salts		
	Plug grown seedlings	480ppm
	General production	960 ppm
Sodium Absorption ratio		4 (no unit)
Sodium (Na)		69 ppm (3meq/L)
Chloride (Cl^-)		71 ppm (3meq/L)
Nitrogen (N)		10 ppm (0.72 meq/L)
	Nitrate (NO_3^-)	10 ppm (0.16 meq/L)
	Ammonium (NH_4^+)	10 ppm (0.56 meq/L)
Phosphorus(P)		1 ppm (0.3 meq/L)
	Phosphate ($H_2PO_4^-$)	1 ppm (0.01 meq/L)
Potassium (K)		10 ppm (0.26 meq/L)
Calcium (Ca)		120 ppm (6 meq/L)
Magnesium (Mg)		24 ppm (2 meq/L)
Sulfur (S)		20-30ppm(0.63.94meq/L)
	Sulfate (SO_4^-)	30-45ppm(0.63-0.94meq/L)
Iron (Fe)		0.2-4.0 ppm
Manganese (Mn)		1.0 ppm
Boron (B)		0.5 ppm
Copper (Cu)		0.2 ppm
Zinc (Zn)		0.3 ppm
Fluoride (F)		1.0 ppm
Aluminium (Al)		5.0 ppm

(Castilla, 2000)

8. Other Aspects of Drip Irrigation Management

Well-designed drip irrigation systems must apply the water uniformly, in such a way that the different emitters discharge almost the same rate. A good management must maintain a good emission uniformity that is easy to quantify.

Physical, chemical and biological agents can be responsible of the emission uniformity decay, due to clogging. Physical clogging can be prevented with a good filtration of the water and regular flushing of the lines and emitters.

Chemicals clogging are normally originated when the soluble salts precipitate on emitters as water evaporates from emitter surfaces between irrigation runs. Injected chemicals (fertilizers, pesticides) are also responsible for frequent clogging. Most cases of chemical clogging can be solved by acid treatment or injection. Acid injection to reduce the pH of water between 1 and 2 should be adequate, while, in severe clogging cases, emitters must be soaked in dilute acid solution (approx. 1%) and even cleaned individually (Fereres, 198l). Acids are highly corrosive and extreme caution must be observed with their use. Surfaces in contact with acid solutions should be of stainless steel or plastic, and must be rinsed well after contact with acid. The biological clogging can be solved with the injection of a biocide followed by flushing to clear the system of organic matter.

Conclusion

A well designed microirrigation system must be properly managed to attain a high level of application uniformity in order to obtain a fairly good water use efficiency. The use of Class A evaporation pan radiation method and tensiometers may be helpful for the estimation of water requirement and irrigation scheduling. Various other techniques such as use of mulch can be used to further enhance the water and nutrient use efficiency along with improving the quality of produce and precise resource savings. Automation further reduces the manual intervention and increases the input use efficiency.

REFERENCES

- Ayers, R.S., Westocot, D.W. 1976. Calidad del agua para la agricultura. Estudio FAO: Riego y Drenaje n°29. FAO. Roma. 85 pp.
- Boulard, T., Baille, A., Lagier, J., Mermierm, M. 1989. Watervapor transfer and dehumidification in a inflatable plastic greenhouse. Acta Hort. 245: 462-469.
- Boulard, T., Baille, A., Gall, F.L., 1991. Etude de différentes méthodes de refroidissernent sur le climat et la transpiration de tomates de serre. Agronomie, 11: 543-553.
- Castilla, N., 1986, Contribucion al estudio de los cultivos enarenados en Almería: Necesidades hídricas y extracción de nutrientes del cultivo de tomate de crecimiento indetermineando en abrigo de polietileno. Tesis Doctoral. Caja Rural Provincial. Almería. 196 pp.
- Castilla, N., 1989. Programation de l'irrigation gouteà-goutte en serre plastique non chauffée. Plasticulture, 82:59-63.
- Castilla, N., 1990. Technology transfer on the use of localized irrigation. Proc. XI Int. Congr. "The use of plastics in Agriculture". New Delhi. India. Vol l-B: 33-39.

- Castilla, N., Fereres, E. 1990-B. The climate and water requirements of tomatoes in unheated plastic greenhouses. Agricoltura Mediterranea 120: 268-274.
- Castilla, N., Fereres, E., 1990-C. Tomato growth and yield in unheated plastic greenhouse under Mediterranean climate. Agric. Medit. 120(1): 31-40.
- Castilla, N., 1994. Greenhouses in the Mediterranean area: Technological level and strategic management. Acta Hort. 361: 44-56.
- Castilla, N., 2000. Greenhouse drip irrigation management and water saving. Cashiers Options Mediterraneennes , 31: 189-202.
- Doorembos, J., Pruitt,W.O. 1976. Las necesidades de agua de los cultivos. Estudio FAO: Riego y Drenaje n" 24. FAO. Roma. 194pp.
- Fereres, E. 1981. Drip irrigation management. Univ. of California. Berkeley (Calif). 39pp
- Hanan, J.J. 1990. The influence of greenhouse on internal climate with special reference to Mediterranean regions. Acta Horticulturae 287:23-34.
- Martinez , A. and Castilla, N.1990. Evapotranspiración del pimiento en invernadero en Almería. ITEA, 85: 57-62.
- Orgaz, F., Bonachela, S. Cuevas, R., Rios, E., Fereres, E., Escalada, S. NMontero, J.I., Lopez, J., Castilla, N.G 1986. Evaluación de sistemas de riego localizado en cultivos bajo invemd la provincia de Almería. ActaIsI Congreso Nacional de S.E.C.H. C6rdoba (Españaj. vol.1: 509-517.
- Rana, S. and Sah, R. 2010. Study of the effect of protected environment on pan evaporation and water requirement of different vegetables. U. G. Dissertation, GBPUA&T., Pantnagar
- Sirjacobs, M. 1986. Protected cultivation of sweet pepper in arid zone: Evaluation of water requirements and amounts per watering. Acta Horticulturae, 191:199-207.
- Stanghellini,C., 1993. Evapotranspiration in greenhouses with special reference to Mediterranean conditions. Acta Hort. 335: 295-304.
- Stanghellini, C. 1994. Balance hídrico y manejo de microclima en invernadero. IT[." Tecnología de invernaderos". Alvarez and Parra (Ed.) Junta de Andalucía. Almería (Spain):49-62.
- Stegman,E., Musick J., Stwart, J. 1980. Irrigation water management. In: "Design and operation of farm irrigation system". JENSEN M.E. (Ed), ASAE Monograph n°3. Michigan(USA): 763-816.
- Vermeiren, I., Jobling., G.A. 1980. Localized irrigation: design, installation, operation, evaluation FAO Irrigation and Drainage paper n"36F. AO. Roma. 203 pp.
- Veschambre, D., P.vaYsse. 1980. Mémento goutte a goutte: Guide pratique de la micro-irrigation par goîîteur et diffuseur. C.T.I.F.L. Paris2. 04 pp.
- Villele, *O.,* 1984. Les besoins en eau des cultures sous serre. Com. Troisième Journee Nationales des Techniques Horticoles dePoints. Hortiforum-84. Orleans. 15 pp.

An Overview on Seed-borne Diseases and Effective Protection against Them

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

There are two ways for improving the output of food production:

1. Increase productivity

2. Avoid crop failures

This duality hold true, in particularly in relation to the fundamental demand for better seed. For food sufficiency India underwent introduction of new crops or high yielding varieties of indigenous planting material, particularly the seed. Of course, it helped India to sustain its food security via green revolution but at the same time there had been challenges of introduction of many seed-borne plant pathogens which later established or posed problems time to time for successful crop production.

Pathogens thus, introduced remained confined to some regions initially, but later spread all over the country. The diseases which used to be of minor importance became the major diseases in the regions where pathogen established and disseminated.

There have been the evidences that the infected or contaminated seeds at an early stage can lead to proliferation of microorganisms through out crop production leading to substantial crop losses an at times to epidemic proportion. Thus, the seed which is the key input for all crop cultivation has the potential for trans-boundary spread of plant diseases and serves as primary source of inoculum for disease epidemics.

Seeds are both the vectors and victims of diseases. Over the years, there has been a long list of seed-borne pathogens which have been intercepted during cross boundary trade by NBPGR in India through seed or planting material. With the movement of seed, which is often produced in one country, processed and packaged in a second and sold and planted in another, comes an increasing danger of the spread of seed-borne diseases.

It is estimated that 30% diseases are of seed borne nature and can be managed through disease-free seeds. The losses due to seed-borne diseases in developing countries are estimated to be 60-80% higher than in industrialized countries. Conservatively estimated, seed-borne diseases cause losses in the order of 50 million ton of food annually.

Impact of poor seed health/ seed borne pathogens

- Leads to poor seed germination to various degrees,
- give rise to pre- and post emergence seedling mortality and progressive disease development in the field and thereby reduces the yield and quality of the crop
- contaminate previously disease-free areas,
- spread of the diseases across national or international boundaries,
- reduce shelf life of the seed, and

- affects food safety /mycotoxins /nutritional value.

Significance of Seed-borne pathogens

In worst-case scenario, seed-borne diseases can be disastrous and even life threatening. Consumption of molded grains of wheat, millet, and barley with *Fusarium* killed thousands of human beings in the USSR in 1913 after World War II due to toxin production by the fungus.

Effect of Seed borne diseases in crop production

The major component of losses due to seed borne pathogens are :

1. Quality loss,
2. cost of planting restriction,
3. loss of seed export ,
4. additional cost of transportation ,and
5. yield losses.

Few examples which exemplify the significance of seed borne pathogens and their effect on seed production are: Blast of rice (*Pyricularia oryzae*) which had been so much so devastating and was held responsible for famine in Japan in 1930. Yield losses had gone upto 100% due to loose smut in wheat (*Ustilago segatum* var. *tritici*) in Georgia.

Brown spot of rice (*Drechslera oryzae*) ,a devastating disease, was held partly responsible for Bengal famine in 1942-43 in India. The fungus is major components of the dirty panicle syndrome of rice. Another menace to wheat is glume blotch (*Septoria nodurum*) , known to be present serious in many European countries , USA and India causing substantial losses in wheat productivity.Losses due to Karnal bunt of wheat in North Western Mexico have been estimated to an average of $7.02 millions/year. An unexpected spread of ergot (*Claviceps microcephala*) in bajra from multiplication centres in Maharashtra to many region of the states(Punjab, Rajasthan and Uttar Pradesh) in India had caused damages to an extent that many crops had to be burnt in order to prevent further ravage and spread(1968). The seed borne nature of blight (*Ascochyta rabiei*) has been well known in Punjab and North West UP (Neergaard 1968). Menace to chickpea by Ascochyta blight (*Ascochyta rabiei*) has happened in the year 1982-1984 in India and Pakistan. The diseases occurred in serious proportions and caused substantial yield losses. In severely infected fields no seed setting could be observed.

Sunflower downy mildew (*Plasmopara helianthi*) was unknown in India until 1984. In 1985, it has been reported to occur in a serious form in Maharashtra. The causal fungus *Plasmopara helianthi* is considered to be of North American in origin. It has been distributed rapidly by seed trade. Observations indicated the large scale reduction in yield due to attack of this disease. In Canada the losses attributed due to Helminthosporium Leaf Blight (HLB). *Bipolaris sorokiniana*" have been equivalent to $42millions in 1971.

Resurgence of diseases

Spot blotch or Helminthosporium Leaf Blight (HLB) : *Bipolaris sorokiniana"*resurged in

serious proportion during 2008-2009 in different districts of Sindh and Punjab. Farmers in Sindh were celebrating the spring festival in March 2009 anticipating a rich wheat harvest from their fields due to ideal environmental conditions. But after the harvest, the situation for many changed and their happiness turned into gloom when they found that the yield was contrary to their expectations. The yield reduced from 6.0 tons/ha to a mere yield of 1.6 to 2.2 tons/ha from their potential lands.

Several bacterial diseases are well established in seed stocks. Few examples are: bacterial blight in rice (*Xanthomonas oryzae*); common bacterial blight of bean (*X. phaseoli*); black rot of crucifers (*X. campestris pv. campestris*); and Black arm in cotton (*X. malvacearum*); These diseases caused major menace to the respective crop production.

Bacterial blight of paddy was 1st observed in Mahrashtra (formerly Bombay) State in 1951, when it was reported in Kolaba District but it was not until 1963 that an outbreak of disease occurred accounting for total crop failure as happened in Punjab, Haryana and Western Uttar Pradesh States of India in 1979 and 1980. In India, the disease has accounted for more than 20% rice crop loss, periodically. Most Seed borne viruses are asymptomatic and transmit efficiently through infected seed and further disseminated by a number of vectors. The losses are attributed to the environmental conditions and the prevalence of the vector population in that area. For example, one infected plant will produce 100% infected seed (soybean mosaic virus) such seed will be viable and germinate well, but the resulting plants will be infected and yields will be significantly reduced. All these examples exemplify the significance of seed borne pathogens and their effect on seed production.

New Challenges

With the new dimensions in Indian agriculture, which is not only confined to the varietal developments by conventional breeding for crop improvement in yield and quality traits but for value addition and for food biosecurity, new tools are being used for crop improvement, (transgenics, or BT crops) by way of biotechnology. This may change the scenario of the pathogens and plant diseases in agriculture. Thus, a threat form exotic destructive pests is foremost importance in the era of liberalized import under WTO. However, the changing conditions the indigenous pests already existing but having the lower damage level in India are changing their habit and gaining importance over the years.

Resurgence of seed-borne diseases: cropping system

With the change in cropping system there is resurgence of diseases. Examples are necrosis in sunflower and ground nut that can not be neglected for crop production and food security. Apart from the threat posed by resurgence, a large number of diseases are endemic and continue to cause losses in given area ,example is Karnal Bunt of Wheat.

Resurgence of seed-borne diseases: Chemical pesticides

With the excessive use of chemical pesticides, number of resistant strains of pests have evolved which are the constant threat and need improved measures for disease management

Seed-borne diseases and Seed health: perspective

Role of seed sector in agriculture

As a consequence of increased product liability and competitive pressure with in the seed industry, seed health has also become an important quality trait in market place. In industrialized countries, the formal seed sector provides the vast majority of seed to farmers where the seed health issues are well taken care of. Inspite of large investments in formal seed systems in developing countries over the past 30 years, about 90–95%, of smallholder farmers' seed demands are still met by informal sources at farm and community level.

Seed health in relation to crop production

The microorganisms associated with seeds can be overtly pathogenic, asymptomatic or latent in seeds, and therefore if unsupported by a definite seed health test may cause a typical disease syndrome or otherwise interfere to reduce final yield and quality of the produce.

Risk associated with import

Seed health testing helps in checking the transboundary introduction of alien species of plant pathogens which once introduced may be devastating or are difficult to get rid off .

Seed health testing helps in anticipating the effective disease management choices and thus helps in reducing the cost of production which otherwise would have been expensive. For healthy seed production seed health certification program must go hand in hand with proper seed processing.

More-over seed health testing is one of the important tools for monitoring seed quality and advisement for seed treatment.

Seed Health Testing

The demand and pressure for seed health testing is however increasing to deliver healthy seed to farmers and seed producers. SPS (Sanitary and Phytosanitary) issues in WTO are pressurizing the developing countries to give special attention to seed health testing and to respect International Phytosanitary Regulations (IPR) issues.

Seed health management

Seed health management needs to be focused on:

- Estimation of losses attributed to seed-borne inoculum
- Predictive relationships between seed-borne inoculum and disease incidence
- Developing reliable, effective, cheap and rapid detection methods
- An understanding of pathogen tolerance in a seed lot before a technique is an acceptable clinical seed health test.
- Establishment of seed health certification schemes
- Decisive proper seed processing and seed treatment

Advances in Seed Health Testing

The first *International Rules for Seed health Testing* was published by ISTA in 1928. This document contained a special section on *Sanitary Condition* in which special attention was recommended for *Claviceps purpurea, Fusarium, Tilletia,* and *Ustilago hordei* on cereals;

Ascochyta pisi on peas, *Colletotrichum lindemuthanium* on beans; and *Botrytis, Colletotrichum linicola,* and *Aureobasidum lini* on flax. The demand for better seed quality, greater sensitivity and shorter turnaround times for seed testing is forcing seed health testing laboratories to incorporate new technologies which will provide the user with a significant level of reliability, sensitivity, and reproducibility of the test . In last 35 years, several seed health testing procedures, published by International Seed testing Association (ISTA) are now obsolete and need to be revised or revalidated by newer technology due to fast pace of technological development.

Seed Testing Methodologies

- Many conventional seed health testing methods have been developed such as:
- agar plating
- blotter test
- seedling bioassay
- microscopic observation
- Direct isolation of pathogens
- growing on test
- However, they are multi-stage, and are often slow, cumbersome time consuming, labour-intensive and subjective.

Seed Health Test Organization

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

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 amongst these was 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) until 2002, when the PDC was finally designated to SHC. In first several decades SHC of ISTA focused on cataloguing seed-borne microorganisms rather than the practical aspects of detecting pathogens in a phytosanitary context. 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 International Seed Health Initiative-Vegetables (ISHI-Veg) started in 1993 as an initiative of the vegetable seed industry. International Seed trade Federation (ISF) started two more ISHI's (ISHI for herbage crops in 1997 and ISHI for field crops in 1999). These ISHI's put more emphasis on quarantine pathogens and their impact on the international seed trade. In 2002

all the seed health testing methods were validated and accepted according to the ISTA rules and published as “Hand book of method validation” 2002.In 2005 ISTA–SHC emphasized **the** validity of a test protocol and characterization of new seed borne pathogens .

Non destructive seed health test

Indexing the seed for health through non destructive seed health test is carried out by methods like:

- Ultra sound
- Optical and infrared analyses, and Biopsis

Advances in Indexing Seed for Pathogen

Several advances in seed health testing have been made such as:

- Liquid plating assay (seed-borne bacteria)
- Enzyme-Linked Immunosorbent Assay (seed-borne viruses)
- Serology and
- Polymerase Chain Reaction (PCR)/ molecular biology based techniques

Serological Methods

These methods are generally simple to perform, rapid and accurate when used, generally to detect a number of bacterial and viral pathogens even if present in low level. These methods are being applied for many seed borne pathogens successfully, for example

Indexing seed for lettuce mosaic virus was started as grow-out assay on several thousand seedlings (30,000) Later the test was changed to indicator host plant *Chenopodium quinoa test.* Further ,since 1983, ELISA (enzyme-linked immunosorbent assay), has been used which not only proved to be more efficient but very sensitive in detecting low levels of infections that could potentially threaten lettuce production.The lack of sensitivity and ambiguity in results and inability to detect all strains of the pathogen sometimes limits their use.

Indirect Immuno-fluorescence Colony Staining Method

Used for detection of seed-borne bacterial pathogens. The test is especially suitable for seed companies, and quarantine stations which have no facilities for conjugation of primary antiserum. The assay is easy to perform and quick to be assessed. Choosing the right secondary conjugate is however, necessary to get best results in the assay.

Nucleic acid based detection methods

Highly sensitive BIO-PCR methods have been developed for several bacterial pathogens from seeds, including *Pseudomonas syringae pv. Phaseolicola, Acidovorax avenae ssp. Avenae, Xanthomonas oryzae pv. oryzae and X. campestris pv.campestris* .

A DNA-based polymerase chain reaction (PCR) has been developed as an alternative or supportive method to a costly and time consuming grow-out test (10,000 seedlings) for detecting (*Acidovorax avenae sub sp. citrulli*), the cause of watermelon fruit blotch .

Molecular Methods

Certain laboratories are testing the D-Genos ready-to-use kits to detect certain seed borne

bacterial pathogens (*Pseudomonas savastanoi* pv. *phaseolicola* and *Xanthomonas axonopodis* pv. *phaseoli* on bean seeds) .The data obtained are conclusive enough to allow the use of D-Genos kits for routine testing as an alternative to standard procedures.

Populations of two fungal pathogens of rice - Bipolaris oryzae (Cochliobolus miyabeanus),(brown spot) and Saracladium oryzae, (sheath rot) - were used as model pathosystems.Methods were developed to characterise these organisms using polymerase chain reaction (PCR) with both random amplified polymorphic DNA (RAPD) and simple-sequence repeat SSR oligonucleotides as primers.

Ustilago nuda infection of barley seed can be readily detected by PCR using primers Uh 1 and Uh 4 when the seed has a high level of infection. However, a better DNA extraction method is needed in order to detect the required limit of 0.2%. The fungal pathogens which are difficult to be distinguished on the basis of colony characters or on spore morphological characters owing to their similarity, PCR based assays are the right answer in such cases.

Constraints in seed health testing on routine basis

To date there has been no systematic attempt to evaluate the large number of test procedures for their appropriateness, whether in terms of cost, ease of use, but even more importantly their scientific validity.

Challenges for seed health testing in Seed Industry

- Require greater emphasis by plant protection authorities on seed health testing
- Reliability of tests questioned
- Harmonisation of tests
- Use of protocols suitable to test seed.

Chemigation under Protected Cultivation

P. K. Singh
Department of Irrigation and Drainage Engineering, G.B.P.U.A.&T., Pantnagar- 263 145 (UK)

Chemigation is the precise application of agricultural chemicals (fertilizers, fungicides, herbicides, insecticides, nematocides, soil conditioners, growth regulators and bio agents) into water flowing through an irrigation system and is an efficient and economical means of applying inputs necessary for crop, nursery, green house and landscape management. This is possible through application of right amount of agricultural chemicals at right time, at right place and in right manner :

- to achieve high yield and the quality produce
- along with minimization of ground water / surface water pollution

The sustainable management of soil is possible through application of right amount of fertilizers /nutrients and other chemicals at right time, at right place and in right manner to achieve high yield and the quality of produce along with minimum / no loss to the ground water caused due to nutrient leaching. Fertigation (application of fertilizer / chemical solution with irrigation) has the potential to ensure that the right combination of water and nutrients is available at the root zone, satisfying the plants total and temporal requirement of these two inputs. Fertilizer application through irrigation can be conducted using micro (drip/trickle), surface (border, basin, and furrow), pipe and sprinkler irrigation systems. Micro and subsurface system of irrigation can only be used for fertigation of soil-applied agricultural fertilizers/ chemicals. Surface irrigation methods can, at times, present problems with the uniformity of fertilizer / chemical application and may limit some chemical applications. Sprinkler irrigation system (impact, rain gun, pop-up, centre pivots, lateral move etc.) can be used both for soil and over canopy/ foliar application of nutrients / chemicals.

There are various benefit and risk associated with the application of fertilizers, chemicals and other nutrients under fertigation / chemigation / nutrigation. Proper management and efficient application of these nutrients / chemicals offer significant saving of these chemicals, better scheduling as per crop need, improvement in yield and nutrient use efficiency and less impact on environment which is an important component of sustainable soil management. The main drawbacks associated with fertigation are the initial set-up costs and the need to monitor the operation carefully to ensure that irrigation and injection systems are working correctly. Water quality can limit the use of fertigation; irrigation waters that are high in salts are not suitable for fertigation. Generally the concentration of salts in the fertigation solution should not exceed 3000 micro Siemens per centimeter (µs/cm). The most significant risk when utilizing fertigation / chemigation is for water source contamination due to back siphoning, backpressure, over irrigation and untimely application of N fertilizers, which reduces the efficiency of fertilizer use and compounds N losses to the environment (Ng Kee Kwong and Devile,1987). In addition, nutrient depletion within plant root zone and soil acidification was reported (Peryea and Burrows 1999;

Mmolawa and Or 2000; Neilsen *et al.* 2004) if proper care has not taken during fertigation. Fertigation may favour NO_3-N leaching, which requires a careful calculation of the fertilizer dose to minimize the risk of groundwater contamination.

A well-designed fertigation system can reduce fertilizer application costs considerably and supply nutrients in precise and uniform amounts to the wetted irrigation zone around the tree where the active feeder roots are concentrated. Applying timely doses of small amounts of nutrients to the trees throughout the growing season has significant advantages over conventional fertilizer practices. Fertigation saves fertilizer as it permits applying fertilizer in small quantities at a time matching with the plants nutrient need. Besides, it is considered eco-friendly as it avoids leaching of fertilizers. Liquid fertilizers are best suited for fertigation. In India, inadequate availability and high cost of liquid fertilizers restrict their uses. Fertigation using granular fertilizers poses several problems namely, their different levels of solubility in water, compatibility among different fertilizers and filtration of undissolved fertilizers and impurities. Different granular fertilizers have different solubility in water. When the solutions of two or more fertilizers are mixed together, one or more of them may tend to precipitate if the fertilizers are not compatible with each other. Therefore, such fertilizers may be unsuitable for simultaneous application through fertigation and would have to be used separately. This article reports on the various issues of fertigation i.e. advantages and limitations, selection of water soluble fertilizers (granular and liquid), fertigation scheduling in various crops and fertigation system for efficient fertigation programme and response of plants to fertigation and its economic.

2. Why Chemigation?

- No need to spread the agricultural chemicals (so coverage is more even, and a lot of work is saved).
- Chemicals placement at right place and better uniformity.
- Chemical requirement in coordinate with crop development.
- Efficiency is high – saving of chemicals.
- Controlling the depth of application.
- Working with liquid fertilizers is very convenient.
- Prevent chemical leaching to the ground-water
- Reduces soil compaction caused by tractors & other tillage equipments
- Mechanical damage to the crop by sprayers is reduced by chemigation
- It reduces operator exposure to the chemical
- It may reduce environmental hazards associated with spray drift
- Chemigation of post emergence soil-acting herbicides may reduce phytotoxicity and increase activity.
- Chemical application cost saved by 40% or more.
- Reduces energy consumption by 90%.

Limitations

- Chemigation requires considerable management input and personnel training
- Chemigation requires a change in management techniques
- Some chemical may react with irrigation system components
- Additional equipment may be required for chemigation

3. Selection of chemicals for chemigation

Herbicide Application

- Weed geminates in the top 25-50 mm of soil.
- Therefore, application should be such that herbicide should reach to this depth, not beyond.
- Sprinkler are the most widely used irrigation system for the application of herbicides
- Spray emitters or under tree irrigation system are preferred over drip / trickle irrigation
- Application of nematocides through drip irrigation have been very successful

Selection of herbicides depends on:

- Solubility in water : high - better
- Volatility : Low – better
- Adsorption : to Organic matter and clay should be low

Fungigation : Application of fungicides through sprinkler irrigation

- Centre pivot system : More effective – uniform coverage
- Travelling / rain gun : Less effective – non uniform coverage
- Coverage = f (formulation, amount of water and uniformity of irrigation)
- For effective foliar application use a formulation that is not easily washed off and use less water
- If soil application is desired use formulation that will wash off to a great extent and deposit the majority of the chemical on the soil and use more water per unit area.

Insecticides: Application of insecticides through irrigation system depends on the :

- Nature of insecticides
- Special needs of the crop at various growth stages, and
- Efficacy of the insecticide

- Insecticides can be injected undiluted or they can be diluted with water or oil to a volume necessary for calibrating within the range of the pump.
- For many insecticides, mixing with an oil before injection can improve efficacy and residual control
- Oil carriers should control no emulsifiers
- Studies have shown that insecticide formulation best suited for chemigation are those insoluble in water and soluble in oil
- LEPA (Low Energy Precision Application) centre pivot system modified for chemigation (

low placement of LEPA nozzles) for control of spider mite in corn . However, for shoot borer spray should reach above ear region

- Insecticide level must specially state that the product can be applied through irrigation system

Selection of Fertilizers

Effective fertigation requires an understanding of plant growth behavior including nutrient requirements and rooting patterns, soil chemistry such as solubility and mobility of the nutrients, fertilizers chemistry (mixing compatibility, precipitation, clogging and corrosion) and water quality factors including pH, salt and sodium hazards, and toxic ions. The granular and liquid fertilizers used in fertigation are available in various chemical formulations, solubility and different types of coatings; therefore selection of fertilizer is an important issue in fertigation Programme. The selection of granular fertilizer will depend on the nutrient that is applied, fertilizer solubility and ease of handling.

An essential pre-requisite for the solid fertilizer use in fertigation is its complete dissolution in the irrigation water. Examples of highly soluble fertilizers appropriate for their use in fertigation are: ammonium nitrate, potassium chloride, potassium nitrate, urea, ammonium monophosphate and potassium monophosphate. The solubility of fertilizers depends on the temperature. The fertilizer solutions stored during the summer form precipitates when the temperatures decrease in the autumn, due to the diminution of the solubility with low temperatures. Therefore it is recommended to dilute the solutions stored at the end of the summer. Fertilizer solutions of smaller degree specially formulated by the manufacturers are used during the winter.

Table 1: Fertilizers solubility and temperatures (g/100 g water) (Wolf et al., 1985).

Temperature	KCl	K_2SO_4	KNO_3	NH_4NO_3	Urea
10°C	31	9	21	158	84
20°C	34	11	31	195	105
30°C	37	13	46	242	133

To ensure the fertilizers selected will not precipitate in irrigation pipe, mix the fertilizer solution with sample of irrigation water in the same proportions as and when they are mixed in the irrigation system. If the chemical stays in the solution, then the product is safe to use under fertigation. Liquid fertilizers offer many intrinsic advantages over granular fertilizers for fertigation. It is considered as most suitable for of fertigation under micro and sprinkler irrigation. These are available as fertilizers solutions and suspension, both of which may contain single or multi nutrient materials.

To avoid damage to the plant roots high fertilizer concentrations, the fertilizer concentration in irrigation water should not exceed 5%. Although, the susceptibility to root burning from concentrated fertilizers varies with crops, fertilizers and accompanying irrigation practices,

therefore it is safer to keep the fertilizer concentration of 1-2% in the irrigation water during fertigation.

Water soluble specialty fertilizers

A specialty fertilizer is a concept. The crux is to inculcate intangible concept initially which eventually leads to tangible results (Goel, 2007). These fertilizers are fully water soluble solid fertilizers. They have high content of primary nutrients with low salt index. They may or may not have secondary / micro nutrients. These water soluble fertilizers can be advantageously utilized for foliar feeding and fertigation, thus helping in precision agriculture. Since it is concept it has to be viewed differently with a different approach. In order to use the marketing strength effectively and also to capture critical mass, this business into three segments i.e. foliar application, fertigation and soil application. The market size of water soluble fertilizers in India is presented in Fig.1.

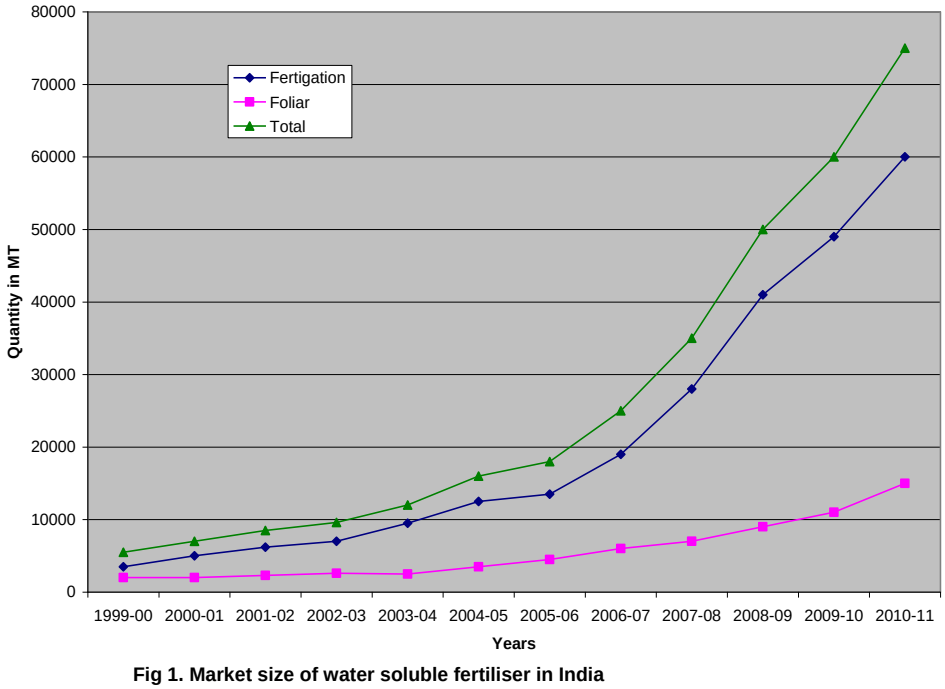


Fig 1. Market size of water soluble fertiliser in India

4. Important Points to be considered during Fertigation

Water quality: The interaction of water having pH values (7.2 -8.5) with fertilizers can cause diverse problems, such as formation of precipitates in the fertilization tank and clogging of the drippers and filters. In waters with high calcium content and bicarbonates, use of sulphate fertilizers causes the precipitation of $CaSO_4$ obtruding drippers and filters. The use of urea induces the precipitation of $CaCO_3$ because the urea increases pH. The presence of high concentrations of calcium and magnesium and high pH values lead to the precipitation of calcium and magnesium phosphates. Recycled waters are particularly susceptible to precipitation due to its high bicarbonate and organic matter content. The resultant precipitates are deposited on pipe walls and in orifices of drippers and can completely plug the irrigation system. At the same time, P supply to

the roots is impaired. When choosing P fertilizers for fertigation with high calcium and magnesium concentrations, acid P fertilizers (phosphoric acid or monoammonium phosphate) are recommended.

Fertigation under saline conditions: Crops vary widely in their tolerance to plants, reference tables are available defining individual crop sensitivity to total soluble salts and individual toxic ions (Maas and Hoffman, 1977). When brackish waters are used for irrigation, we must bear in mind that fertilizers are salts and therefore they contribute to the increase of the EC of the irrigation water. Nonetheless, calculation of the contribution of chloride from KCl to the overall load of chloride from irrigation water shows its relative by low share (Tarchitzky and Magen, 1997).

When irrigation water has an EC > 2 dS/m (with high salinization hazard), and crop is sensitive to salinity, we must decrease the amount of accompanying ions added with the N or K. For example, in avocado - a very sensitive crop to chloride - KNO_3 is preferred on KCl to avoid Cl accumulation in the soil solution. This practice diminishes leaf burning caused by Cl excess. Also in greenhouse crops grown in containers with a very restricted root volume we must choose fertilizers with low salt index. Sodium fertilizers as $NaNO_3$ or NaH_2PO_4 are unsuitable due to the adverse effect of sodium on the hydraulic conductivity and the performance of the plant.

A correct irrigation management under saline conditions includes water application over the evaporation needs of the crop, so that there is excess water to pass through and beyond the root zone and to carry away salts with it. This leaching prevents excessive salt accumulation in the root zone and is referred to as *leaching requirement* (Rhoades and Loveday, 1990).

Fertilizers compatibility: when preparing fertilizer solutions for fertigation, some fertilizers must not be mixed together. For example, the mixture of $(NH_4)_2SO_4$ and KCl in the tank considerably reduce the solubility of the mixture due to the K_2SO_4 formation. Other forbidden mixtures are:

- Calcium nitrate with any phosphates or sulfates
- Magnesium sulfate with di- or mono- ammonium phosphate
- Phosphoric acid with iron, zinc, copper and manganese sulfates

The use of two fertilization tanks allows to separate the fertilizers that interact and cause precipitation, placing in one tank the calcium magnesium and microelements, and in the other tank the phosphorus and the sulfate.

Soil pH: The pH values for optimal availability of all the nutrients are in the rank of 6-6.5. The main factor affecting pH in the rhizosphere is NH_4/NO_3 ratio in the irrigation water specially in sandy soils and inert substrates with low buffer capacity such as rockwool. Rhizospheric pH determines the phosphorus availability since it affects the processes of precipitation/solubilization and adsorption/desorption of phosphates. The pH also influences the availability of micronutrients (Fe, Zn, Mn) and the toxicity of some of them (Al, Mn).

The nitrogen form absorbed by the plant affects the production of carboxylates and the cation-anion balance in the plant. When NH_4 absorption is predominant, the plant absorbs more

cations than anions, H^+ ions are excreted by the roots and rhizosphere pH decreases. Fluctuations of pH of the ground around the roots of the order of 1.5 units of pH due to ammonium or nitric nutrition have been reported in the literature (Barber, 1984). According to Ganmore-Neumann and Kafkafi (1980, 1983), NH_4 is an undesirable source of nitrogen for tomato and strawberries when the temperature in the root zone is greater than 30°C, due to its adverse effect on root growth and plant development. The pattern of cationic uptake due to ammonium nutrition decreases the uptake of other cations like Ca^{2+}, Mg^{2+} and K^+.

When NO_3^- anions are absorbed, the plant takes up more anions than cations and the excess of anions is palliated by a greater synthesis of carboxylates. During the carboxylation process dicarboxylic acids (citric, malic, etc.) and OH^- are produced.

Both the carboxylates and the hydroxyls can be exuded by the roots to the soil The exuded OH^- increase the pH of the rhizosphere The organic acids exuded by the roots increase the availability of phosphorus since the carboxylates are specifically adsorbed to iron oxides and clays of the ground, releasing therefore adsorbed phosphorus to the soil solution. The carboxylates can also increase to the availability of iron and phosphorus by chelation: for example, citrate forms a chelate with calcium, thus releasing phosphorus that is under the calcium phosphate form (Imas et al., 1997).

According to this, NO_3 nutrition is recommended due to the greater organic acid synthesis and enhanced cations uptake, whereas the ammonium nutrition is detrimental However, nutrition with 100% nitrates would increase rhizospheric pH up to undesirable values - values of more than 8 have been registered - and this would decrease the availability of P and micronutrients by precipitation. Therefore it is recommended to use a nitrogen mixture with 80% of nitrates and 20% of ammonium to regulate pH.

5. The Fertilization Program

- **Crop Nutrients requirements:** It depend on crop specific needs, yields, methods of growing (open / protected cultivation) and variety. The crop specific need may be asses by mineral analysis of harvested part and vegetative biomass, ratio between N-P-K-Ca-Mg and percent dry matter. Based on mineral analysis and the yield / plant ratio, one may estimate the crop need for a specific yield and for each ton produced not proportional.
- **Soil analysis:** How much N, P, K, Ca, Mg to apply.
- **How much nutrients to apply :**
    - **Vegetables:** Fertilization=soil deficit correction + crop nutrients requirement (removed+plant)
    - **Field crops :** Fertilization=soil deficit correction + removed by yield (harvested
    - **Orchards**: Fertilization=soil deficit correction + removed by yield

No soil anylysis: The following factor may be used

N total x (1.2 -1.3) – depend on soil type i.e. lower for heavy soil and higher for

light soil

P total x (1.3-2.2) – depends on pH and soil type. It increases from light to heavy textured soil and also increases as pH increases (5-8)

K exported x 1.4 - depends on soil type, it decreases from low to heavy texture.

- **Method of application :** Surface, sprinkler and micro irrigation
- **Choice of fertilizers :** Granular and liquid
- **Timing and quantity to apply :** Growth curve based fertilizer requirement and scheduling

6. Fertilizer Use Efficiency (FUE) under Drip-fertigation

Fertigation facilitates the application of water and nutrients directly into the plant root zone, leading to greater efficiencies of application and uptake. This has been substantiated for various crops in studies carried out across the world. Goel, 2007 reported that fertilizer use efficiency of nitrogen is as high as 95% under drip-fertigation as compared to 30-50% under soil application (Table 3).The results of studies carried out on sugarcane in Maurititus (Ng Kee Kwong et. Al., 1999) and Australia (Dart *et al.*, 2000; Ridge and Hewson, 1995), indicated increase in nitrogen (N) fertilizer use efficiency up to 30%.

Table 3: Fertilizer use efficiency of various nutrients under fertigation

Nutrient	Fertilizer Use Efficiency		
	Soil application	Drip	Drip + Fertigation
Nitrogen	30- 50	65	95
Phosphorous	20	30	45
Potassium	50	60	80

Timing of fertigation to coincide with periods of demand from the crop (growth curve nutrition) is a common method of maximizing fertilizer efficiency in many high value crops with complex phonology and nutrition requirements. However, Buller *et al.* 2002 reported that splitting nitrogen applications evenly over the first four months of sugarcane crop development lead to more efficient and productive use of nitrogen than the growth curve nutrition approach. In another study conducted on sugarcane cultivation under drip-fertigation at PFDC Pantnagar, India showed that sub-surface drip irrigation under paired row planting at 75 cm x 75 cm spacing gave the highest cane yield in main (129.84 tonnes / ha) as well as ratoon (137.46 tonnes/ha). This treatment was significantly superior by recording increase of 35.67 % in main and 40.15 % in ratoon crop over surface irrigated sugarcane planted at 75 cm x 75 cm spacing (PFDC Pantnagar annual report 2009). Patel and Rajput, 2004 reported that fertilizer saving of 40% could be achieved with fertigation system over conventional practice in okra crop without affecting the yield. They also reported that more than 16% increase in yield under fertigation (16.59 – 25.21%) over broadcasting at the 100% level of recommended fertilizer application.

7. Chemigation System

System EU shall not be less than 85 percent where fertilizer or pesticides are applied

through the system. Injectors (chemical, fertilizer, or pesticides) and other automatic operating equipment shall be located adjacent to the pump and power unit, placed in accordance with manufacturer's recommendation and include integrated back flow prevention protection. Fertigation/ nutrigation/ Chemigation shall be accomplished in the minimum length of time needed to deliver the chemicals and flush the pipelines. Application amounts shall be limited to the minimum amount necessary, as recommended by the chemical label.

Design Considerations: Fertigation is the application of fertilizer through an irrigation system. Although used extensively in agriculture for decades, it has been less embraced in the landscape irrigation industry. But today, the increase in environmental, legal, and maintenance cost concerns, coupled with the demonstrated advantages for improved plant growth and health, make a compelling case for fertigation. A properly designed fertigation system must consider all applicable laws, plant material and fertilizer types, proper irrigation design, and the necessary components/methods available, while weighing the cost/benefit concerns of the project.

Component/methods: The last major step is determining the injection method and materials of the fertigation system. The preceding steps will have already determined some of the injection systems requirements. In irrigation system, there are two primary means of injection. One is using a venturi-type system. The other is a positive displacement, usually electrically driven, pump. Advantages of the venturi system are its relative ease of operation, non-reliance on electrical power, reliable operation, and accurate dosing. The disadvantages include smaller degree of adjustability, larger pressure losses in the system, and susceptibility to clogging/flow restriction for proper calibration and operation.

The advantages and disadvantages of the positive displacement pump are more or less the opposite of the venturi system with one primary exception. If properly designed, installed, and used, their accuracy can equal or even exceed that of the venturi system. The next consideration involves material components. The selection of plastics, brass, stainless steel, etc. is determined by the chemicals used, anticipated contact time, costs, and durability issues. Plastic components are usually unaffected by most chemicals but are less durable than stainless steel. Stainless steel, while probably the most durable of the three, is also the most expensive. Most components of the average fertigation system will be made of plastic. Lastly is backflow prevention. While backflow is a must when any potable water supply is used, it may also be required when using lakes and wells.

The irrigation tank itself or separate tank may be used as fertigation system in the gravity fed irrigation. The required concentration of nutrient solution are prepared in the tank and delivered through the system network to the plant root zone. Some time, the suction line of the pumping unit may also be utilized for the fertigation.

Fertilizer applicators: A number of different techniques are used to introduce the fertilizers into the irrigation system Generally, fertilizers are injected into irrigation systems by three principal

methods namely, (1) fertilizer tank (the by-pass system), (2) the venturi pump and (3) the injection pump (piston or destron pump). Non-corrosive material should be used for the fertilizer containers and for the injection equipment.

8. Design of Irrigation System Considering Chemigation

After determining the type of irrigation delivery system, it is important to design the system so that it delivers fertigated water as uniformly as possible. Distribution uniformity (D.U.) should be in the 80% or higher range. This means 20% or less of the applied water will be wasted. If lower D.U.s are used, some plants will not receive adequate fertilization while others will be over-fertilized. This will occur with any D.U. below 100%, so the higher the D.U. the more effective the fertigation. Second, the system must be able to meet the scheduling demands dictated by local regulations, proper horticultural practices, and the fertigation system itself. It is generally desirable to have all fertigated water flushed from the system at the end of the irrigation cycle. So the fertigation system should be designed to deliver fertilizer fast enough to allow the system to operate, after fertigation, for a long enough period of time to flush all lines. This should occur without having longer-than-required run times for providing the necessary water to the landscape. While this is often possible in smaller systems, larger systems often retain some fertigated water after the watering cycle. At minimum, the system must be designed to allow the required amount of fertilizer to be applied during normal watering run times. The following steps can serve as a general guide for making the above determinations.

First, calculate the LPH for each zone (to determine precipitation rates) and the required run time to provide optimum water for the plant material. Second, determine the volume of water in the piping from injection point to the furthest sprinkler, in each zone. Now compare these two figures for each zone and determine which zone has the largest required run time to receive fertigated water. This will be the "critical zone" for fertigation design purposes. Using the quarter/half/quarter rule (system runs for one-fourth of its total programmed run time before fertilizer injection begins, injection occurs for half the run time, injection ceases for the final one-fourth of the run time) determine the allowable fertigation run time within the zone's "total run time." Finally, determine what concentration the fertilizer will need to be at to fit inside this "fertigation window."

This is the point where compromises may have to be made between complete flushing of piping, realistic concentrations and injection rates. The only component that should not be compromised is the overall run time for each zone. The correct amount of water should always be delivered to the plant material. Excess water should not be applied just to allow fertigation. This would be counter-productive. The fertigators have more flexibility on using liquid fertilizers as compared with water soluble granular fertilizers.

9. Conclusions

The precision farming and hi-tech agriculture for the improved input use efficiency, more

yield and quality produce in sustainable manner is incomplete without efficient irrigation and fertilizer application techniques. Chemigation is the most efficient techniques of chemical / fertilizer application in split manner as per crop need at different stages of crop development. In the present paper various aspect of fertigation has been discussed. The fertilizers used for fertigation must be 100% water soluble and it should not precipitate while making the solution. The selection of fertilizers should be in accordance with the pH of soil. The concentration of fertilizer should not be more than 2% during fertigation. The fertilizer requirement should be determined based on soil analysis and if soil analysis not possible certain correction factors must be applied depending on the soil texture. The fertilizer use efficiency can be maximized by adopting drip-fertigation to the level of 95%. The drip- fertigation system should be appropriately designed to achieve at least 85% of uniformity of water and fertilizer application. The piston pump type of fertigation unit is most efficient system of fertilizer application. However, fertilizer tank and ventury type of fertigation unit is most common at the farmer's field because of its low cost.

REFERENCES

- Dart IK, Baillie CP and Thorburn PJl. 2000. assessing nitrofen application rates for subsurface trickle irrigated cane at Bundaberg. Proc Aust Soc Sugar Cane Technol 22:230-235.
- Ganmore-Neumann, R. and U. Kafkafi. 1980. Root temperature and percentage NO_3^-/NH_4^+ effect on tomato plants. I Morphology and growth. Agron. J. 72:758-761.
- Ganmore-Neumann, R. and U. Kafkafi. 1983. Root temperature and percentage NO_3^-/NH_4^+ effect on strawberry plants. I Growth, flowering and root development. Agron. J. 75: 941-947.
- Goel MC. 2007. Fertigation/chemigation scheduling of liquid fertilizers for various crops. In: Proceeding of the workshop on micro irrigation held at WTC IARI New Delhi pp 36-59.
- Maas, E.V. and G.J. Hoffman. 1977. Crop salt tolerance - current assessment. J. Irrig. Drainage Div. ASEC 103: 115-134.
- Mmolawa K and Or D.2000. Rootzone salute dynamics under drip irrigation : A review. Plant Soil 222:163-190.
- Neilsen GH, Neilsen D, Herbert LC and Hogue EJ.2004.Response of apple to fertigation of N and K under conditions susceptible to to the development of K deficiency. J Am Soc Hortic Sci 129:26-31.
- Ng Kee Kwong KF and Devile J.1987. Residual nitrogen as influenced by timing and nitrogen forms in silty clay soil under sugarcane in Mauritius. Fertil. Res.14:219-226.
- Ng Kee Kwong KF, Paul JP and Devile J.1999. Drip-fertigation a means for reducing fertilizer nitrogen to sugarcane. Expl Agric.35:31-37.
- Patel N and Rajput T B S.2004. Fertigation – a technique for efficient use of granular fertilizer through drip irrigation. *IE(I) Journal-(AG)* 85:50-54.
- Peryea F J and Burrows R L .1999. Soil acidification caused by four commercial nitrozen fertilizer solutions and subsequent soil pH rebound. Commun Soil Sci Plant anl 30:525-533.
- PFDC Pantnagr. 2009. Annual report 2008-2009 PFDC, G. B> Pant University of Agriculture & Technlogy, Pantnagr, Uttarakhand.
- Rhoades, J.D. and J. Loveday. 1990. Salinity in irrigated agriculture. In: Irrigation of Agricultural Crops. B.A. Stewars and D.R.Nielsen (Eds.). ASA-CSAA-SSSA, Madison, WI. pp 1089-1142.

- Ridge DR and Hewson SA. 1995. Drip irrigation management strategies. Proc Aust Soc Sugar Cane Technol 17:8-15.
- Scaife, A. and B. Bar-Yosef. 1995. Nutrient and fertilizer management in field grown vegetables. IPI Bulletin No. 13. International Potash Institute, Basel,
- Switzerland.Wolf, B., J. Fleming and J. Batchelor. 1985. Fluid Fertilizer Manual. Vol. 1. National Fertilizer Solutions Association, Peoria, Il.
- Tarchitzky, J. and H. Magen. 1997. Status of potassium in soils and crops in Israel, present K use indicating the need for further research and improved recommendations. Presented at the IPI Regional Workshop on Food Security in the WANA Region, May 1997, Bornova, Turkey.

Biological Control of Soil Borne Pathogens under Green House Conditions

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

Global scenario of green house/protected cultivation: Green house cultivation is a form of protected cultivation which has some level of control over plant microclimate to alleviate one or more of abiotic stress for optimum plant growth. The green house technology is more than 200 year old and Europeans were considered the pioneers in this field. Later with the advent of plastic during World War II a new phase in the glass house technology emerged. The world's total greenhouse area is more than 307,000 ha which includes both plastic and glass poly houses. There are more than 50 countries in the world where cultivation of crops is undertaken on a commercial scale under cover. Green houses permit production of crops even in areas where winters are severe and extremely cold as in Canada and Russia, and also in areas where summers are extremely intolerable as in Israel, UAE, and Kuwait.

Country wise area under green house crop production

Country	Area under green house production
USA	>400 ha
Spain	25,000 ha
Italy	18,500 ha
The Netherlands	89,600 ha
Israel	15,000 ha
Egypt	1000 ha
China	48,000 ha
Japan	>40,000 ha
South Korea	>21,000 ha

Status of Green house cultivation in India: In India green house technology is still in its nascent stage. The area under green/poly house cultivation, in the end of 2011 was about 2000 hectares. Maharashtra, Uttarakhand, Karnataka and Jammu & Kashmir are the major states having cultivation of crops under green house. According to the Directorate of Horticulture, Govt. of Uttarakhand, in 2011, the total area under polyhouse in Uttarakhand is 200ha. Vegetables, flowers, medicinal and aromatic plants are considered as most successful and revenue generating crops grown in this technology. All these crops have high productivity in green houses due to reduction in competition, healthy environment, better nutrient management, increased surface area and longer crop duration.

Disease Problems in Greenhouses: The ideal and stable environment with warm, humid and abundant food under green house provides an excellent platform for the development of diseases often more than field conditions. Most pathogens cannot be excluded from the greenhouse environment, for example airborne spores enter through doors and screens; soilborne pathogens enter through dust or contaminated soil on shoes, tools, or equipment; and many pathogens are

introduced on seeds or contaminated propagating materials. Zoosporic pathogens get entry through irrigation water, and insects transmit both fungal inoculum and viruses. The optimum conditions like temperature, light, and fertilizer not only maximize plant growth but also favourable for pathogens. Moreover, warmth and humidity, due to the water vapour transpired by the plants and the lack of air exchange with the outside, provide ideal conditions for foliar pathogens such as *Botrytis* and powdery mildews. Because of high energy costs, ventilation is often reduced to prevent loss of heat. Disinfested soil or soilless substrates such as peat or rock-wool lack the microbial diversity and biological buffering present in a natural soil. In this biological vacuum, soilborne pathogens such as *Pythium* and *Rhizoctonia* can quickly grow and spread. High-density planting of greenhouse crops increases the relative humidity and the chances of disease spread, and management practices such as pruning and harvesting, increase the spread and infection through wounds. Hydroponic systems (rockwool, nutrient film, or ebb and flow) present another set of disease problems. In this closed recirculating system, zoosporic pathogens can easily spread in the water system.

Considerations of biocontrol in green houses: The protected nature, expensive crops and microclimatic conditions in the green house make it rather imperative to suitably alter the disease management strategies as per the requirements. There is lack of specific chemicals suited for green house conditions. Due to high registration and development costs and the lack of return on investment act as deterrents to chemical companies in registering products for the relatively small greenhouse market. Containment of toxic fumes from pesticides are hazardous to green house workers. Workers are at greater risk of fungicide exposure in the greenhouse because of the intensive nature of crop management.

Most fungicides require a re-entry period before the workers can return to a treated crop and there is a harvest interval, a period of time between the last application and harvest. Moreover, many greenhouse crops are continuously harvested and therefore cannot use most fungicides. Due to frequent harvesting and direct table value of the produce, pesticides with lower waiting periods only can be used. Breakdown, weathering, and wash-off of chemicals on the leaves or in substrates are all lower in greenhouses than in the field, so fungicides may have a longer residual activity. Finally, the development of fungicide resistance in the pathogen may be exacerbated by the intensive use and limited choice of fungicides in the greenhouse. There is increasing societal concerns about the environmental and health effects of fungicides. Large sprayers cannot be used in green houses due to the limitation of space. Therefore, the grower must be extra careful in the long range planning, selection, use and application of pesticides in green house crop cultivation systems. That's why agriculture in greenhouses and protected structures offers a unique niche for the development and use of biological control agents.

Suitability of biological control for greenhouses: Of the commercial biocontrol products over half have applications in nurseries or greenhouses and many were specifically developed against

the soilborne pathogens *Pythium* and *Rhizoctonia*, which are major greenhouse pathogens. The use of biocontrol is more prevalent in greenhouse and protected structures than in field crops, even though greenhouses account for only 0.02% of the area used in agriculture. Some of the very conditions that favor disease also favor the management of diseases with biological control agents. Environmental conditions such as temperature and relative humidity can be tightly controlled. Like the pathogen, biocontrol agents are also sensitive to environmental conditions, and an unfavorable environment in the field has been cited as a reason for failure or inconsistent performance. Conditions in the greenhouse can be optimized for the biocontrol agent. For instance, biocontrol agents of powdery mildews are much more efficient when relative humidity can be maintained above 80%, a condition that is easily monitored under glasshouse conditions. The biological vacuum in soil substrates can also favor the establishment of biocontrol agents, provided they are applied before pathogen introduction. Logistics and economics of applying biocontrol agents in the greenhouse:

Products registered for biological control of soilborne pathogens: Several formulations of either of the fungi *Gliocladium-Trichoderma* or the bacteria *Pseudomonas* and *Bacillus* have been widely used for biocontrol of soilborne pathogens. These products are not only registered as biofungicides but also used as plant strengtheners. In European countries, plant strengtheners include inorganic compounds such as SiO_2, $NaHCO_3$, organic constituents such as compost, homeopathic compounds, and some containing microorganisms such as *Trichoderma harzianum, Bacillus subtilis, Pseudomonas,* and *Pythium oligandrum.* Details of available biocontrol agents for green houses are as follows:

1. ***Coniothyrium minitans****: Coniothyrium minitans* is a mycoparasite which destroys sclerotia of *Sclerotinia sclerotiorum* and *S. minor.* It is used for the control of Sclerotinia wilt of lettuce in greenhouse and rape in the field. *C. minitans* reduced the sclerotial populations at the soil surface, survived at least 39 weeks at a density of 10^4–10^5 CFU/g, and spread to infect sclerotia in control plots.
2. ***Gliocladium virens (Trichoderma virens)*****:** It is a soilborne fungi, developed for control of *Pythium ultimum* and *Rhizoctonia solani* in soilless mixes. The fungus produces two fungitoxic compounds, glioviren and gliotoxin compounds.
3. ***Trichoderma harzianum:*** *T. harzianum* reduces Fusarium crown and root rot of tomatoes grown in potting mix containing *T. harzianum* and transplanted into the field. In greenhouse trials, *T. harzianum* controlled *R. solani* in poinsettia, geraniums, and *Catharanthus*, and *Pythium* on geraniums, impatiens, and petunias. It inhibits the pathogens by mycoparasitism via production of chitinases, ¼ 1-3 glucanases and ¼ 1-4 glucanases, antibiotics, competition, solubilization of inorganic plant nutrients, induced resistance, and inactivation of the pathogen's enzymes involved in the infection process.
4. ***Streptomyces griseoviridis:*** This culture is marketed in Europe and USA, under the

name of Mycostop. It was originally isolated from sphagnum peat and was tested as a biocontrol agent against Fusarium wilt of carnations in commercial greenhouses.

5. ***Gliocladium catenulatum***: It is a mycoparasite effective against damping-off, seed rot, root rot, and wilt pathogens. It is sold as a wettable powder that can be applied to the soil, roots, or foliage. In glasshouse trials with ornamental bedding plants, application by incorporation into the growing mix or drench reduced damping-off caused by *Pythium and Rhizoctonia.* In some cases*, G. catenulatum* was as effective as the fungicides propamocarb or tolclofos.
6. **Non-pathogenic *Fusarium oxysporum:*** It is effective against Fusarium wilt diseases on carnation, tomato, cyclamen, and Fusarium crown and root rot on tomato. Mechanisms of action include competition for carbon, direct competition with pathogenic strains, and induction of host defenses.
7. ***Bacillus subtilis* var*. amyloliquefaciens:*** Several strains of *B. subtilis* tested on cucumber and tomato against *Pythium aphanidermatum* and *Phytophthora nicotianae* in a series of greenhouse trials. It shows growth promotion effect on corn and radish. *FZB C* and *G* strains of *B. subtilis* produced peptide antibiotics active against *F. oxysporum* f. sp*. radicis-lycopersici.*

Biological control of greenhouse diseases in India: In India, integrated pest management research has not matched the progress and problems of plant protection at large and green house cultivation in particular. *Trichoderma harzianum* and *T. viride* are the most common fungal bio-agents used for suppression of soil borne plant pathogens. *Pseudomonas fluorescens,* used as addendum to FYM, effective against *Fusarium oxysporum, Pythium* spp, *Rhizoctonia* solani, *Phytophthora* spp., *Sclerotium rolfsii* and nematode parasites. The following table shows important diseases of green house crops in India and their biocontrol.

Diseases	Crops	Management
Powdery mildew	Capsicum, cucumber	*Bacillus subtilis* (10g/l)
Downy mildew	Cucumber	*Bacillus subtilis* (10g/l)
Fusarium wilt	Tomato, cucumber	*Trichoderma* spp. (10g/m^2), *Pseudomonas fluorescens* (10ml/m^2)
Damping off	Capsicum, cucumber	*Trichoderma* spp. (10g/m^2), *Pseudomonas fluorescens* (10ml/m^2)
Fruit rot	Tomato	*Bacillus subtilis* (10g/l)
Root knot nematode	Capsicum, cucumber, tomato	*Trichoderma* spp. (10g/m^2), *Pseudomonas fluorescens* (10ml/m^2)

Biocontrol agents and ecology: The use of living organisms to combat other living organisms presupposes a thorough knowledge of their ecology. Efficient root colonization and establishment of biocontrol bacteria is of key importance for effective suppression of deleterious organisms.

Once biocontrol bacteria are established in the rhizosphere, a wide variety of mechanisms can result in suppression of plant pathogens. Accordingly, except in the case of induced resistance, a biocontrol agent must occupy an ecological niche similar to that of the plant pathogen and its mode of action (competition, parasitism, antibiosis, induction of SAR) must interfere both spatially and temporally with precise steps in the development of the pathogen.

Interactions between plants and rhizobacteria: The rhizosphere is a narrow zone of soil that is influenced by root secretions. The structure of rhizobacterial communities is determined by the plant species, and differences in the composition and amounts of root exudates probably account for the differences in microbial populations. Root exudates offer a carbon-rich diet to the rhizosphere microorganisms which includes organic acids such as citrate, malate, succinate, pyruvate, fumarate, oxalate and acetate and sugars such as glucose, xylose, fructose, maltose, sucrose, galactose and ribose, constitute the 'main course', whereas variable amounts of amino acids, nucleobases and vitamins (such as thiamin and biotin) provide the 'entrée' or 'dessert'. The ability of rhizobacteria to use organic acids as carbon sources correlates with rhizosphere competence. The rhizosphere, which is the narrow zone of soil that is influenced by root secretions, can contain up to 10^{11} microbial cells per gram root and more than 30,000 prokaryotic species. The collective genome of this microbial community is much larger than that of the plant and is also referred to as the plant's second genome. Chemotaxis, flagellar mobility, lipopolysaccharide (LPS) structure, the outer membrane protein OprF and, to a lesser extent, pili are all important for competitive root colonization. A root glycoprotein complex, agglutinin involved in the short-term adherence of Pseudomonads to the plant roots. Once biocontrol Pseudomonads have moved and attached to a root zone, microcolonies form in a few days. Other bacteria can reach the same site at a later time and intermingle with pre-existing microcolonies. The root collar, where the root joins the main stem, is a site of intense exudation and is more strongly colonized by bacteria than is the root tip.

The rhizosphere microbiome: The microflora of most soils is carbon starved. Because plants secrete up to 40% of their photosynthates into the rhizosphere, the microbial population densities in the rhizosphere are much higher than in the surrounding bulk soil. This phenomenon is known as the 'rhizosphere effect'. In general, rhizosphere microbial communities are less diverse than those of the bulk soil. It appears that, from the reservoir of microbial diversity that the bulk soil comprises, plant roots select for specific microorganisms to prosper in the rhizosphere. Together with the plant genotype, soil type is an important driver of the microbial community composition in the rhizosphere. Plants can determine the composition of the root microbiome by active secretion of compounds that specifically stimulate or repress members of the microbial community. Recent evidences suggest that plant genotype also determines microbiome composition. Differences in a single gene between plant genotypes can have a significant impact on the rhizosphere microbiome. The production of a single exogenous glucosinolate significantly altered the microbial

community on the roots of transgenic *Arabidopsis*.

The root microbiome to the rescue: Microbiome changes upon defense activation i.e. the interactions between a plant and its root microbiome might change when the plant is attacked. Recently, it was demonstrated that infection of citrus by *Candidatus Liberibacter asiaticus*, associated with Huanglongbing, drastically altered the composition of citrus rhizosphere communities. Also, *Verticillium dahliae* infections affected the microbial composition of cotton rhizospheres. Changes in rhizosphere composition upon infection might be the result of the induced excretion of antimicrobial compounds by infected roots. However, infection does not only lead to the secretion of pathogen deleterious compounds. It is also found that infected roots also induced excretion of pathogen spore germination stimulators. For example infection of water melon plants by *F. oxysporum* enhanced the stimulation of *Fusarium* spore germination by root exudates.

In addition to this recent researches shown that plants recruit plant beneficial microbes to their roots in response to the attack. For eg.- colonization of the roots of *Arabidopsis* by the plant-beneficial soil bacterium *Bacillus subtilis* FB17 was greatly improved when aboveground plant tissues were infected by *Pseudomonas syringae* pv. *tomato*. A mutually beneficial relationship exists between *Arabidopsis* and FB17: *FB17* is recruited to aid in plant defense, and the plant provides the bacterium with malic acid. Activation of beneficials : inoculation of strawberry plants with *Verticillium dahliae* stimulated the expression of cyanide biosynthetic genes in the biocontrol bacterium *Pseudomonas* sp. *LBUM300*. These changes in gene expression could be a result of nutrients leaking from damaged roots.

Future perspectives: Use of biocontrol agents in green houses is quite successful in European countries. In Britain, although protected crops represent a small fraction of the total area, they account for two thirds of all biologicals. At the same time, the use of pesticides in greenhouses has declined from 4866 treated ha in 1981 to 2292 ha in 1995. A combination of economic, political, and environmental factors has probably contributed to the transition to biological due to the loss of insecticide registrations, insect resistance, and concern for worker safety.

Limitations with the use of biocontrol: Because of the high value of the crop and emphasis on quality in floriculture, vegetable crops, and ornamentals, there is less acceptance of damage and thresholds for disease are very low. If biocontrol agents cannot perform with the consistency and efficacy of fungicides in these crops, they may not be adopted. Control of microclimatological conditions. The success of bioagents depends on the quality, timely availability and appropriate release timing and methodology of bioagents. Given that a biological control strategy is scientifically feasible, the successful grower is most likely to adopt the strategy if it is an economically feasible decision for the greenhouse. The adoption decision is economically feasible for the grower if expected profits are greater than zero (i.e. expected revenues are greater than

expected costs). If growers habitually make decisions where expected profits are less than zero the greenhouse will not be a viable business in the longer run.

Future Research Priorities: More scientific efficacy trials with proper replication and statistical analysis are needed under commercial or near-commercial conditions. Biocontrol registrations now request data on the interaction of pesticides with beneficial insects. Growers need to know whether new products are compatible with their current pest management strategies. Knowledge of epidemiology and ecology of pathogens in the greenhouse, which may be different from the field is required. Low-cost methods for rapid detection of pathogens in the greenhouse are important research priorities. Finally, the challenge of production and formulation of biocontrol agents remains, with each organism bringing its own set of problems. Effective production and formulation protocols are usually proprietary, involving substantial investment to develop economic production and a formulation with adequate shelf life, stability, and titer.

Greenhouses offer a privileged environment for disease biocontrol, but implementation is still very limited. However, if we have anything to learn from our entomologist colleagues, it is that this will change. Indeed, from a modest and uneven start in the early 1970s, insect biocontrol has grown to a standardized approach throughout the greenhouse market. Plant pathologists and companies investing in biocontrol products should likewise view the future of biological control of plant diseases in greenhouse systems with optimism. A few products have already been registered and several more should be commercialized within the next few years. Success stories against a number of diseases will be important both to validate biocontrol of plant diseases and, most important, to gain acceptance by growers.

REFERENCES

- T.C.Paulitz and Belanger, R.R.2001. Biological control in greenhouse systems. Annu. Rev. Phytopathol.39:103-133.
- Berendsen, R.L. ; Pieterse, C. M.J., and Bakker, P. A.H.M. 2012. The rhizosphere microbiome and plant health. Trends in Plant Science. 17:

Hydroponics and Plant Disease Management

Alok Shukla
Department of Plant Physiology, G.B.P.U.A&T., Pantnagar- 263 145 (UK)

Hydroponics is derived from a Greek word “hydros’’ meaning water and “ponos’’ meaning labour i.e., working with water. It is soilless culture i.e., growing plants without soil. Several civilizations have utilized hydroponic techniques and the records available reflected several hundred years B.C as of Egyptian hieroglyphic records. Historical examples are “The hanging gardens of Babylon and the floating gardens of the Aztecs of Mexico which describe the growing of plants in water." Hydroponics is hardly a new method of growing plants.

William Frederick Gericke from the University of California, Berkeley campus has first coined the term hydroponics in 1937.

Basic concept of Hydroponics

The main concept of hydroponics depends on criteria of essentiality given by Daniel Arnon and Perry Stout in 1939 as

- Plant cannot complete a function and cannot complete its life cycle
- A deficiency can be corrected only by application of the specific element that is deficient
- The element plays a direct role in the metabolism

The essential elements are absorbed by the plant roots as inorganic ions. These elements are characterized as macro and micro elements depending upon their requirements. Generally if the element is required as less than 100 ppm it is classified as micro element and if it is required as more than 100 ppm it is known as macro element. Besides absorbing carbon, oxygen and hydrogen from the atmosphere and water all the other elements are absorbed as ions of their respective elements as nitrogen as NH_4^+, NO_3^- phosphorus as HPO_4^{2-}, $H_2PO_4^-$,potassium as K^+ , calcium as Ca^{2+} , magnesium as Mg^{2+} ,sulphur as SO_4^- , boron as H_3BO_3, BO_3^- , copper as Cu^{2+} , iron as Fe^{2+}, Fe^{3+} , manganese as Mn^{2+} , zinc as Zn^{2+} , molybdenum as MoO_4^- , chlorine as Cl^- , cobalt as Co^{2+} and nickel as Ni^{2+} ions. The common nutrient solution used for hydroponic culture is Hoagland solution.

Composition of a modified Hoagland nutrient solution

Compound	Conc. of stock solution(mM)	Conc. of stock solution(g/L)	Element	Final conc. of element (ppm)
Macronutrients				
KNO_3	1000	101.10	N	224
$Ca(NO_3)_2.4H_2O$	1000	236.16	K	235
$NH_4.H_2PO_4$	1000	115.08	Ca	160
$MgSO_4.7H_2O$	1000	246.49	P	62
			S	32
			Mg	24

Micronutrients				
KCl	25	1.864	Cl	1.77
H_3BO_3	12.5	0.773	B	0.27
$MnSO4.H_2O$	1.0	0.169	Mn	0.11
$ZnSO4.7H_2O$	1.0	0.288	Zn	0.13
$CuSO4.5H_2O$	0.25	0.062	Cu	0.03
$H_2MoO_4.H_2O$	0.25	0.040	Mo	0.05
NaFeDTPA	64	30.0	Fe	1.00-3.00

These ions are supplemented either in solution culture or in the inert medium of sand, gravel, perlite, vermiculite, etc.

Components of hydroponic system

- **Growing chamber** (or tray), It is required for holding the root system
- **Styrofoam** It is a trademarked brand of closed-cell extruded polystyrene foam.The sheets of styrofoam is used for placing small seedlings by making holes
- **Reservoir** It is required for holding the nutrient solution
- **Submersible pump** It is required for providing water to the plants
- **Delivery system** to get the water/nutrients from the pump in the reservoir to the plants, and back to the reservoir again
- **Simple timer** to turn on and off the pump, as well as the lights
- **Air pump** and air stone to oxygenate the nutrient solution
- **Lighting** for the lighting one can use many different lighting systems, from compact fluorescent lighting (CFL's) to expensive lighting system

To run a hydroponic system following things must be maintained.

i) Electrical conductivity 1.9 to 3.2 mS

ii) pH 5.5 to 6.5

iii) Light 200-250 µmoles/m^2/sec

iv) Temperature 20-25ºC

There are two main types of hydroponic system

i) Solution culture

ii) Medium culture

Solution culture

This system does not require any inert substrate .It is also known as liquid hydroponic system. There are different ways of operating the same.

i) Water culture

This is the simplest form of hydroponics in which nutrient solution circulates with the help of a pump. Nutrient solution is kept in a reservoir and is connected with troughs .The troughs are either metallic trays or cemented material. On the troughs styrofoam sheet is placed. Small holes

with respect to crop are made on the sheets for holding seedlings. Roots of the seedlings remain in touch with the circulating nutrient solution nutrient solution. An aerator is also needed for supply of oxygen to roots. 10-12 hour nutrient solution run is sufficient for optimum absorbtion.

ii) Wick Technique

It doesn't require any pump. Plant roots get nutrients through wick from the reservoir.

iii) Nutrient Film Technique

The NFT systems provide a constant film of water and nutrients along the bottom of a channel. In effect, part of the roots grow down in the water/ nutrients and parts of the roots above the water line getting fresh air and oxygen

iv) Flood and Drain System

It is the most versatile. Each time the water floods from the lower reservoir into the upper growing tray, the roots are bathed in the fresh nutrients. When the nutrient drains back to the reservoir, fresh air is drawn through the root system refreshing oxygen to the roots.

v) Aeroponics

It is the misting of plant roots in air. It was developed in the last century at the University of Pia in Italy by Dr. Franco Massantini. It has been proven and refined for decades and is used by scientists around the world, including NASA (National Aeronautics and Space Administration). Aeroponics uses 65% less water than hydroponics. NASA also concluded that aeroponically grown plants requires ¼ the nutrient input compared to hydroponics. Unlike hydroponically grown plants, aeroponically grown plants will not suffer transplant shock when transplanted to soil, and offers growers the ability to reduce the spread of disease and pathogens. Aeroponics is also widely used in laboratory studies of plant physiology and plant pathology. Aeroponic techniques have been given special attention from NASA since a mist is easier to handle than a liquid in a zero gravity environment.

Aeroponics plants

- Receive their required daily nutrients
- They avoid contact with soil borne pests and fungus
- They grow up to 50% faster

Medium culture

It requires various substrates as sand,gravel,peat,perlite,vermiculite,rockwool.Besides the above techniques for growing plants under hydroponic system an important way of integrating aquaculture and fish culture also exists called as Aquaponics

Aquaponics

It can best be defined as a combination of aquaculture and hydroponics. In aquaponics the fish and plants are produced in a single integrated system, where the fish waste provides a food

source for the plants and the plants provide a natural filter for the water in which the fish live.

Potential application of Hydroponics

The potential application of hydroponics is the production of fresh produce in nonarable areas of the world. This alliance of hydroponics and military was tested during World War II when soldiers stationed on remote, infertile Pacific islands used hydroponics to grow healthy produce to supplement their rations. Later in the century, hydroponics was integrated into the space program. NASA has incorporated the hydroponic system for the space craft's in providing fresh vegetables to astronauts.

Hydroponics is an attraction for the scientists, analysts, traditional farmers and eager hobbyists. The positive aspects of hydroponics include:

- The ability to produce higher yields than traditional, soil-based agriculture
- Allowing food to be grown and consumed in areas of the world that cannot support crops in the soil
- Eliminating the need for massive pesticide use (considering most pests live in the soil), effectively making our air, water, soil, and food cleaner
- Ending hunger and making the world cleaner

In addition to the extensive research that is going on, everyday people from all over the world have been building (or purchasing) their own hydroponic systems to for getting fresh food under protective and sustainable agriculture.

Disadvantages of hydroponics

- Hydroponic production is management, capital and labour intensive.
- A high level of expertise is required.
- Daily attention is necessary.
- Specially formulated, soluble nutrients must always be used.

Plant diseases and their management in hydroponics

In hydroponics the plants are genetically identical and uniformly susceptible .The dense planting can favour movement of pathogens from infected to healthy plants. The physical environment, temperature and humidity favour the pathogens. In closed system, where the water circulates the zoosporic pathogens can easily spread from one plant to other. The zoosporic pathogens produce a flagellated asexual swimming spore that can readily move in water and infects the roots. The most common species in the genera are

- Phytopthora
- Pythium
- Olpidium (can also act as a vector of viruses as lettuce big vein)

Zoosporic pathogens can cause

- Root rots
- Seedling rots

- Stunting
- Yield loss

Common diseases are

Gray mold (botrytis)

Botrytis cinerea is the causal agent of gray mould. It is a common fungus, with a very wide host range and can persist in the hydroponic cultures year-round as mycelium, conidia, or as sclerotia on living or dead tissue. If the humidity goes beyond 85% and air circulation lowers down the fungus produces a large amount of spores on the plant surface, germinate, and penetrate the host plant. Cutting stubs are particularly susceptible to gray mold infection. Fungal symptoms are characterized by the presence of fluffy, gray/brown mycelium that produces a cloud of spores if disturbed. Affected tissue is soft and brown, and sometimes has a water-soaked appearance.

Environmental control inside hydroponic system is the best remedy for the gray mould. To control the spores of the fungus the relative humidity should be maintained below 85%.A good air-circulation, ventilation and adequate plant spacing are the appropriate ways of controlling the fungus.

Powdery mildew

Powdery mildew are well defined family of obligate parasites grow abundantly on foliage of the angiosperms and damage wide variety of crops. In hydroponic system the severity reflects with white spots, necrosis, chlorosis and death. Use of silicon, as potassium silicate, at 100 mg L-1 at 3.9-4.0 mS/cm EC of nutrient solution reduced the incidence of powdery mildew significantly in tomatoes .

Wilts

Verticullum Wilt and Fusarium Wilt- Wilt diseases start as small spots on the leaves of tomato, peppers or eggplants. The lower leaves start to curl up, dry out and wilt. Sometimes, portions of the plant may wilt suddenly. These can be prevented by using only fresh, clean medium for each planting, and using resistant varieties of tomatoes

Tobacco mosaic virus

TMV remains on tobacco leaves for years.It can be introduced the hydro garden by the hands of smokers. Smoking in the grow room is not allowed.Smokers must wash their hands thoroughly with soap and water before touching anything in your garden area.

Role of iodine in hydroponic cultures

Iodine is a dark, dense, crystalline solid (4.96 g/ml) at room temperature, which slowly dissolves in water to form a concentrated solution (in equilibrium with its crystallised form) of approximately 250 ppm (0.25g/litre). Iodine is a potent broad-spectrum biocide, even at low concentrations (1–2ppm). When in contact with micro-organisms such as bacteria, viruses,fungi and protozoa, iodine is able to rapidly penetrate the cell wall and oxidise a number of critical components within the cell. The combined effect of these oxidative reactions is cell death.

- To kill all the *Pythium* spores, a concentration of iodine of 5 ml/1000 L was needed for 30 minutes or 10 ml/1000 L was needed for 5 minutes
- The *Fusarium* is basically twice as tough. To kill all the *Fusa rium* spores, a concentration of iodine 20 ml/1000 L was needed for 5 minutes

In general hydroponic system needs prevention and following steps are essential for management of different diseases.

To prevent disease

- The hydroponics facilities undergo constant cleaning with the removal of all waste materials, plant waste, algae on floors and walls and water on the floors.
- Diseased foliage should be promptly cut from plants and removed from the growing area along with other waste material
- To prevent disease ingress, the nutrient solution, medium and roots should be regularly sterilized.
- No-one who has been handling fresh fruit and vegetables can enter hydroponics without first washing their hands and changing their clothing
- Smokers cannot enter the facility unless they have washed their hands and replaced their clothing. Tobacco can carry the mosaic virus which afflicts tomatoes and capsicums
- Daily monitoring for introduced invertebrates, fungi and disease is carried out.
- 'Sterilizing agents' must yield a 'residual' chemical when dissolved in the working nutrient solution so that the entire system is treated each time plants are watered.
- There are a variety of disinfectants available for hydroponic systems. "Oxidizing agents" have historically been most popular. They include
- Chlorine dioxide
- Sodium hypochlorite
- Monochloramine
- Hydrogen peroxide
- UV and ozone.
- However, monochloramine has the advantage of possessing a long half-life, is gentle on roots, and is compatible with the majority of 'organic' mediums and growth promoters.

Biological control in hydroponic system

- Biocontrol would seem to be ideally suited for soilless systems in closed structures. Environmental conditions in greenhouse are more uniform and can be adjusted to make conditions favourable for the growth of biocontrol agent and unfavourable for the pathogen. Due to lack of competition from other microbes as of soil biocontrol is result oriented in hydroponic systems.
- Fluorescent pseudomonas has been used against Fusarium wilt of carnation (*Dianthus caryophillus* L.)

- *Bacillus subtilis* (Ehrenberg) Cohn. partially controlled *F.oxysporum and phytopthora* diseases on tomatoes in hydroponic culture

  Biocontrol can take a lead in the management of plant diseases with native strains. This will help in the development of pesticide free hydroponic system for better health and sustainable hydroculture.

REFERENCES

- Arteca,R.N. and Arteca,J.M.2000.A novel method of growing *Arabidopsis thaliana* plants hydroponically.Physiol.Plant.,108,188-193
- Sheikh,B.A.2006.Hydroponics:Key to sustain agriculture in water stressed and urban environment, Pak.J.Ag,Ag. Engg., Vet Sci.,22:53-57
- Khalil,S. And Alsanius B.W.2010.Evaluation of biocontrol agents for managing root diseases of hydroponically grown tomato Pl. Dis. and Prot.117:214-219
- Paulitz, T.C.1997.Biological control of root pathogen in soilless and hydroponic systems. Hort Sci. 32:193-196
- Stanghalleni, M.L.and Rasmussen,S.L.1994. Hydroponics: A solution to zoosporic pathogen.Plant Dis.,78:1129-1138
- Taiz,L. and Zeiger,E.2006.Plant Physiology.Sinauer Associates,Sunderland MA.704p
- Zhang, W. And Tu, J.C.2000. Effect of ultraviolet disinfection of hydroponic solutions on Pythium root rot and non –target bacteria. Europ. J. Pl.Pathol. 106:415-421

Production and Management of Capsicum in Greenhouse

Dhirendra Singh
Department of Vegetable Science, G.B.P.U.A.& T., Pantnagar-263 145 (UK)

Capsicum (*Capsicum annum*) or important vegetable crops as it is constituents of many foods, add flavor, colour, vitamin C. Capsicum is an important crop in the USA where the five major producing states are florida, California, Texa, New Jursey and north Carolina. In India, it is relatively a new entrant mainly grown in Himachal Pradesh, Uttar Pradesh, parts of Gujrat, Maharashtra, Karnataka, Ranchi region of Bihar and hilly regions of Tamil Nadu. It grows well in summer season in hills and cooler season in the plains.

A greenhouse production system of capsicum differs greatly from the traditional field capsicum cultivation system where plants are grown under polyethylene sheet greenhouse. Greenhouses can be a means to economically maintain a warm environment during cool season, to protect capsicum plants from rain, wind, and high solor radiation, and to retain pollinators and beneficial insects while excluding unwanted insect pests. In greenhouses, capsicum fruits are harvested with full maturation colour and fruit yields are greater of high quality and usually produced at a time of the year when production in the field is not possible and market prices for capsicum are highest. Marketable fruit yields will vary with greenhouse location, growing season, plant density, training system, cultivar, irrigation and fertilizer management.

Why capsicum in greenhouse?

- Prolonged harvesting period (up to 8-9 months).
- Less use of pesticides/chemicals
- Higher yield
- Healthier product
- Higher income
- Self employment

Varieties suitable for Greenhouse production

- Indra
- Bharat
- Tanvi
- Manhattan
- Swarna
- Natasha
- Angel
- California Wonder
- Arka Mohini
- Pusa Deepti
- Solan Hybrid-1

Soil and Types of growing media

1. Soil

- Good soil structure and moisture content are important.
- **Soil**
  - **pH**: 5.5 to 6.5
  - **EC**: 1.5-2.5 mS/cm
- High salt or high nutrient levels are unfavourable.
- The young plants require a good calcium and nitrate supply to establish root system within a week.

2. Nutrient film technique (NFT)

Water culture system where a shallow stream of nutrient solution covers the root of growing plant to provide water, nutrients and oxygen.

3. Soilless media

- Rockwool
- Polyurethane
- Pine bark
- Perlite

Soilless Culture Systems

- Internationally, capsicum crops are grown in the soilless culture in greenhouses.
- Plants are grown in containers filled with soil less media such as perlite, pine bark or peat mixes.
- Media can be reused for several crops (2-3) if disease contamination does not occur.
- Containers are aligned in single or double rows, leading to plant population densities of 0.27 to 0.36 plants per square foot.
- Yields have been found similar with any of the substrate like perlite, pine bark or peat perlite mixes.
- Pine bark – A promising media, because of its low cost, availability, lack of phytotoxicity and excellence as a plant production media.

Optimum seed sowing time

Sowing time in northern region is from 15th August to 15th September.

For higher germination of seed -

- Use fresh, high-quality polyhouse recommended virus-free seeds.
- The seed count is 100-140 per gram, and one gram of seed will generally raise about 80-100 plants.
- Seed trays are filled with a high-quality soilless mix, peat, vermiculite, perlite or rockwool flocks.
- The optimal germination temperature is 24-25°C.

- After germination the covering material is removed and the temperature is lowered to 23°C.

The young seedlings require

- good light conditions.
- proper aeration.
- optimum humidity

Transplanting

- Plants are ready for transplanting in 6-8 weeks.
- Plant Spacing
    - Row x Row = 45cm,
    - Plant x Plant = 30cm
- 7-8 plants/m2 should be planted.
- Growth is dependent on temperature and humidity in greenhouse.
    - transplants require a minimum day temperature of 21 - 23°C, and two degrees higher during sunshine.
    - night temperature of 20°C and
    - high humidity (80%)
- The root temperature must be sufficiently high (20-22°C). So for propagation under cold conditions the use of benches or bottom heat is beneficial.
- CO2 enrichment (to 700 ppm) promote growth of the seedlings from the stage where true leaves are expanded.
- High temperature during August adversely affects production but are good for young plant growth.

Humidity

- During transplanting, humidity must be high, but overhead spraying is not advised as it increases the risk of Botrytis.
- Air humidity is best around 80 % for plant growth.

Temperature

- The optimal temperature after planting is 22/21°C (day/night) on the first days, and 23/22°C (day/night) later.
- The root zone temperature should be around 22°C.
    - Lower increases the risk of Pythium.
    - Too high causes too much growth and insufficient flower production.
- High temperature reduces fruit set due to high rates of abortion in late spring and summer, so ventilation and shade materials are required.
- Cold weather affects yield due to poor pollination , earliness in production and delay maturation, so bottom heating during night is recommended.

Pruning and Training

- Greenhouse capsicum cultivars generally have an indeterminate pattern of growth.
- Plants can grow upto 6 ft tall and need vertical support by hanging twines.
- Capsicum plants can be trellised to Dutch "V" system or to "Spanish" system.

"V" System of Training

"V" system of training consists of forming a plant with two main stems by removing one of the two shoots developed on each node and leaving one or more adjacent leaves per node.

Spanish System of Training

In "Spanish" training system, the plant canopy is allowed to grow without pruning. The plants are vertically supported by a structure of poles and horizontal twines extended on both sides of plant rows.

Irrigation

- It is estimated that average water consumption of capsicum plant is 2 litre per day for 8 month crop.
- Greenhouse cultivation enhances WUE compared to field conditions.
- High WUE induces improved fertilizer use efficiency contributing to reduce fertilizer leaching.
- Irrigation should be provided by drip system .
- Mulching and fertigation can be integrated for higher production.

Fertigation

- In capsicum, an yield of 252 t/ha (from 2 crops in a span of 14 months) have been realized by practicing twice a week fertigation at the rate of 160:160:160 kg/ha of N:P:K.
- Basal soil application @50kg/ha need to be applied.
- Water soluble fertilizers available specially for fertigation are suggested than traditional fertilizers.

Flowering

- A young capsicum plant starts flowering about two to six weeks after planting, when it has 7 to 13 leaves.
- The optimal temperature during flowering should be 20 - 21oC on average both day and night.
- Low night temperature decreases pollen viability in capsicum flowers and modify flower structure and makes self pollination less effective.
- Flowers developed at a night temperature below 18°C usually produce a fruit with a 'tail' (elongated, pointing blossom-end).
- A lower temperature during flowering results in less four-loculed fruit, and more three-loculed fruit, or even two-loculed fruit, which is not desired.
- A flower grown under very low temperature (below 10oC at night) would produce a small

flattened fruit.

- Too high temperature(> 28 °C) stimulate blossom end rot.

Pollination

- To ensure the set of high quality fruits use pollinators like bumble bees or honey bees inside the greenhouse.
- Bees make that less fruit are deformed, and that fruit set and first harvest are better and a bit earlier.

Fruit set

- High light and low day temperature are beneficial for setting and first growth of the new fruit.
- The total period from blossom to full-colour ripe fruit is 7 - 12 weeks.
- When fruit set is difficult-
    a) Drop the night temperature to 18°C. The day temperature can stay at 20-22°C.
    b) Increase the CO2 concentration (to 700-1000 ppm).
    c) For setting of the second flush of capsicum fruit, dropping the temperature is not advised, as it will slow down the ripening of the first flush.
    d) Generally the later fruits will set by themselves after harvest of older fruits.

Controlling fruit load

- Young plants can support about four to eight fruit per plant at a time.
- An older crop can have over 10 fruits per plant at a time.
- Fruit load must be controlled by the grower, in order to achieve a reasonable fruit weight (e.g. minimal 150 gram per fruit) and quality.
- The best method to correct the number of fruit is by removing excess.

Weed Management

- Control of perennial or annual weeds is serious problem in capsicum production.
- Non-fumigated fields are treated with pre-plant or pre-emergence herbicides or both, mechanical cultivation and hand hoeing are usually required for weed control.
- Black plastic mulch is an aid in weed control as in drip irrigation, which reduces weed pressure by maintaining a drier soil surface, avoiding diseases infestation.

Stress Management

I. Physiological disorders:

- ❑ Blossom end rot
- ❑ Sunscald
- ❑ Fruit cracks
- ❑ Fruit splitting
- ❑ Fruit color spots
- ❑ Misshapen fruit

- ❑ Elephant Foot

Blossom End Rot (BER)

- BER can be caused by reduced absorption and translocation of Ca into the fruit.
- Ca deficiency can be due to low Ca in media, excessive salinity or moisture fluctuations in the media

Management

- Avoid the conditions of moisture stress or conditions of reduced transpiration.
- Weekly foliar applications of calcium nitrate can have a significant impact on reducing the amount of BER

Sunscald

- Soft, tan coloured sunken lesions develop fruit that are exposed to direct sunlight.

Management

- It is important to adjust pruning practices to ensure that all fruit are shaded from direct sunlight.
- Apply shad net to the greenhouse during the summer months will also help reduce the incidence of sunscald.
- Fruit temperatures over 35°C should be avoided.

Fruit Cracking

- Characterized by the appearance of very fine, superficial cracks on the surface of the capsicum fruit.
- Ruptures on the cuticle at blossom end is Radial cracking or all over the fruit surface is Russeting.
- Fruit cracks may be due to
    - high relative humidity (over 85%).
    - Sudden changes in weather conditions (from hot sunny weather to cool cloudy weather or vise versa).
    - thick walled fruits(>8mm).

Management

- Avoid high humidity
- Use thin walled fruit varieties

Fruit Splitting

- The development of large cracks in the fruit is a direct response to high root pressure.
- Factors that contribute to the development of high root pressure directly impact fruit splitting.

Management

- Adjust the timing of the last watering in the day so as not to water too late.
- Eliminate any night watering cycles.

Color Spots

- Yellow spots can occur on the outer surface of the fruit.
- High incidences occur in summer and in plants grown in high densities with high levels of N.

Management

- Avoid capsicum varieties susceptible to this disorder

Misshapen fruit

- Due to too cool or too warm weather conditions.
- The development of growths within the capsicum usually results from abnormal tissue development in the honey gland of the fruit.

Management

- Ensure that all environmental targets are met and maintained.

"Elephant Foot"-A disorder in soilless capsicum

- A physiological plant disorder not known to occur in soil-grown plants.

- "Elephant's Foot" disorder most likely requires a localized zone around the stem base with high humidity and / or salt accumulation.
- The affected wounded tissues at basal stem are susceptible to entrance of pathogens (that might be carried by a vector, *i.e. Fungus gnats)* leading to rot which collapses vascular system and plant wilts.

Management

- Lower the humidity and salt concentration in the soilless media.

Diseases and their Management

Damping-off

- Caused by species of *Pythium* and *Rhizoctonia solani.*
- Common in soil grown crops.
- In pre-emergence damping-off areas in nursery are seen where no seedlings have emerged.
- Damping-off in young, emerged, seedlings is seen as a toppling over of the seedlings when root systems are destroyed by the fungi.

Management

- Maintain proper sanitation practices in greenhouse.
- Provide optimal soil temperature, watering etc. to the plants.
- Avoid the conditions where young plants are stressed.

Fusarium stem and Fruit rot

- Caused by *Fusarium solani*
- Soft, dark brown or black lesions on the stems at nodes or wound sites.

- Black water-soaked lesions may also develop around the calyx, eventually spreading down the sides of the fruit.

Management

- Clean greenhouse and good sanitation practices.
- Maintain good air circulation and avoid high relative humidity conditions (above 85%).
- Avoid wounding fruit and excessive wounding to the stems.

Gray mould

- Caused by ***Botrytis* sp.**
- Water-soaked spots that rapidly expand into large yellowish-green or grayish-brown.
- Irregular lesions on fruit that are soft and spongy in texture.
- Velvet-like fungus mycelium and spores are produced on the lesion surface under cool and humid conditions.
- The fungus produces overwintering structures called *sclerotia* in addition to other types of spores.

Management

- Prestorage dry heat treatment.
- Hot air treatment at 38 ºC for 48-72 h or
- Hot water treatment at 50 ºC to 53 ºC for 2 to 3 min.

Leaf spot

- Caused by *Colletotrichum capsici*
- Leaves has necrotic areas.
- Small or large lesions on leaves and fruits.
- Stems and petioles may be girdled, and necrosis of inflorescences causes dieback and shrivelling.

Management

- Use fungicide
    - 0.2% Mancozeb
    - 0.1% Blitox 50 (copper oxychloride)
    - 0.1% Bavistin

Leaf spot

Caused by Colletotrichum capsici

- Leaves has necrotic areas.
- Small or large lesions on leaves and fruits.
- Stems and petioles may be girdled, and necrosis of inflorescences causes dieback and shrivelling.

Management

- Use fungicide

- 0.2% Mancozeb
- 0.1% Blitox 50 (copper oxychloride)
- 0.1% Bavistin

Anthracnose

- Caused by *Colletotrichum capsici*
- Seed born.
- Water-soaked lesions on fruit that become soft and slightly sunken.
- Concentric rings within the fruit spots.

Management

- Avoid alternate host and infected plant debris in polyhouse
- Optimize the humidity in polyhouse.

Bacterial soft rot

- Caused by *Erwinia carotovora*
- The fleshy fruit peduncle is highly susceptible and is frequently the initial point of infection.
- Initially, the lesions on the fruit are light to dark-colored, water-soaked, and somewhat sunken.
- The affected fruit hang from the plant like a water-filled bag.

Management

- Use chlorinated wash water to reduce populations of soft rot bacteria and to reduce the risk of infection during washing.
- Allow fruit to dry thoroughly.
- During packing and storage, the fruit should be kept clean and maintained in a cool, dry place.

Pepper Mild Mottle Virus (PMMV)

- Symptoms include the development of obvious bumps on the fruit as well as color streaking and green spotting as the fruit matures.
- Fruit tend to have pointed ends and may also develop sunken brown areas on the surface .

Management

- The virus is spread by the routine handling of the young plants, especially at transplanting.
- Do minimum mechanical activities during cultivation.
- Grow resistant varieties.

Tobacco Mosaic Virus

- The symptoms of infection first appear on the leaf as a necrosis along the main veins accompanied by wilting and leaf drop.
- New growth on the plants may exhibit mosaic symptoms as well as distorted growth.

Management

- Use disease-free seed.

- Grow resistant cultivars.
- Destroy any infected plants.

Tomato Spotted Wilt Virus

- The virus is spread primarily by thrips, particularly the western flower thrips.
- Leaves get blackish-brown circular spots, or tan spots bordered by a black margin.
- Fruit gets orange to yellow spots surrounded by a green margin.

Management

- Control the virus is by controlling the thrips vector through insecticides.
- Do weed control to minimize the population of thrips and virus.

Insect and Pest Management

- Following insects are common problem of greenhouse capsicum-

Pest	Symptoms	Management
Root knot nematode	Root nodulation	Drenching with carbofuran(6g/m^2), *Trichoderma spp.*(10g/m^2) ,*Pseudomonas fluorescens*(10ml/m^2)
Thrips	White or brown spots on leaves, leaf scars, distorted buds, leaves or flowers	Neem oil(0.5 ml/L); Imidachlophid(0.4g/L)
White flies	Defoliation, inter veinal yellowing of leaves,distortion	Neem oil(0.5 ml/L); Imidachlophid(0.4g/L)

Harvesting

- "Unloading" of plant and allowing energy to go in to new growth.
- Capsicum fruit can be harvested when they are harvestable-green.
- Better to harvest all first fruit green at once because if only some fruits are harvested green, the others fruits are more at risk of creaking.
- The last ripe fruit should be harvested after some new fruits have set on that stem.

Harvesting and Packaging

- Capsicum fruit must be harvested with a very sharp, small knife, to get a smooth stem-end appearance, and to minimize damage to other fruit.
- In peak periods frequent harvesting is needed:
    - green fruit once per fortnight
    - coloured fruit once or twice a week
- For market, capsicum fruits are graded by size and shape and pack these fruits in proper

packaging material**.**

Post harvest handling

- To improve post harvest quality, capsicum are cooled before market or storage by hydro-cooling (before packing) or forced air cooling (after packing).
- Capsicum are sensitive to chilling injury below 7°C.
- Typical transit or storage conditions are 7°C to 13°C with high humidity of 90-95%.
- Senescence of capsicum is hastened by exposure to ethylene, so storage with ethylene producing fruit is not recommended.

  Most common post harvest diseases are-Bacterial soft rot , Anthracnose, Gray Mould

Production and Management of Gerbera under Protected Conditions

Ranjan Srivastava
Department of Horticulture, G.B.P.U.A.&T, Pantnagar- 263 145 (UK)

Scientific Name : *Gerbera jamesonii*

Local Name : Gerbera

Common Name : Gerbera, Transvaal Daisy

Seasons in which the crop is grown

Round the year

Origin & History

Gerbera is believed to be native of Asia, South Africa and Tasmania. The genus *Gerbera* was named in honour of a German naturalist, T. Gerber.

Uses/Nutrient values

Gerbera is one of the most important cut-flowers, successfully grown under different conditions in several areas of the world. This success is primarily due to the wide range in colour and shape of the flower. It is also used as a potted flowering plant. The black centered varieties have more demand in the national and international market. The single and semi-double types of gerbera are grown mainly for the garden decoration whereas the double type varieties are grown for cut flower trade.

Botanical Description

Gerber is a member of Compositae or Asteraceac family. Plants are stemless and tender perennial herbs. Leaves are radical, petioled lanceolate, deeply-lobed, sometimes leathery, narrower at the base and wider at the top and are arrange in a rosette at the base. Flower heads are solitary, many flowered, with conspicuous ray florets in 1 or 2 whorls, those of the inner row, when present, very short and sub-tubular and 2-lipped. The flower stalks are long, thin and leafless. Base on the flower heads, they may be grouped into single, semidouble and double cultivar. Flowers are of different colour, shape, size and form.

Area and Distribution

The major gerbera producing states are Karnataka, Maharashra, Tamil Nadu, West Bengal, Uttrakhand, Punjab, Uttar Pradesh, Delhi, J & K and Chandigarh. In India, they are distributed in the Himalayas from Kashmir to Nepal at altitudes of 1300 to 3200 meters.

Climatic requirement

For quality production of gerbera flowers, they need 50% shade conditions. In summers, gerberas can be grown under shade nets houses. A day temperature of 22-25^{0}C and night temperature of 12-16^{0}C is ideal for cultivation. Poor light during winter adversely affects the flowers production.

Soil

A well drained, rich light, neutral or slightly alkaline soil is most suitable for gerbera

production. The pH of soil should be 6.5- 7.5.

Varieties

A large number of commercially important varieties are grown in different parts of the world. Among them, Regina, Nero, Parade, Mix, Alsmeera, Ibiza, Gold Spot, Sunset, Tara, Lyonella, Ornella, Rosetta, Gloria, Alexias Ginna, Monique, Anneke are grown in India under protected cultivation for export purpose.

Soil Sterilization

The soil of the polyhouse/ green house/ shadenet must be sterilized before planting so as to minimize the damage from the microbes. The deep ploughed soil of the beds are treated with formaldehyde (formalin) [2%] and air tightly covered with polythene sheets for 2-3 days. After the treatment, the soil is uncovered and the soil is turned, the gate and the ventilators of the polyhouse are open for air exchange so that the fumes of the formalin may wash off. The soil is then lightly irrigated.

Need for Protected Cultivation

Gerbera, being a shade loving plant, needs about 50% shade for quality bloom production. Moreover, the covered structure protects the plant from storms, winds, frosts, dews, gales and other mischievous of the environment. It also helps maintain a constant and optimum temperature and humidity as required by the plant during the period of growth. It provides an active protection against disease and pests and ensures round the year production of cut blooms.

Propagation

Propagation may be achieved through seeds, cuttings or through dividing. Seed has a short viability, if seeds fail to germinate within about 20 days it is likely the seeds will not germinate at all. Plant grown from seeds can greatly differ from the parent plants. Basal cuttings should be taken in summer the addition of a rooting hormone may increase the success and shorten the time needed from cutting to potting into their own pots. Division should be taken in early spring, with utmost care so as to minimize the damage to the plants root when dividing or transplanting. About 5-6 divisions can be prepared out of a healthy plant. The divisions are planted in the months of July-August. Micropropagated plants of gerbera are nowadays being routinely used as the planting material.

Time of Planting

Gerbera planting is done in two season-spring (January, February and March) and summer (June, July and August), at the time planting it is important that the plants are not planted two deeply. The crown of the plants should be in level with the soil or some what above it. When planted deep fungal diseases easily occur and when planted shallow, shoots will be pulled loose early while cropping.

Spacing

Gerberas are mainly planted on a raised bed system of one meter width. The working

space between the two beds should be 50 cm. The distance between the plants and within the row should be 30x 30 cm.

Nutrient Management

Gerbera requires plenty of organic matter and ample nutrients for proper growth and production. Application of 10:15:20 g NPK/m^2/month during first three months of planting starting from third week and 15:10:30 g NPK/m^2/month from fourth month when flowering starts. Apart from this, spraying of micronutrients like boron, calcium, magnesium and copper @ 0.15 % (1.5 ml) once in a month is recommended to get better quality bloom.

Irrigation/ Water Management

After planting the crop should be sprinkler irrigated upto four weeks of planting and after that drip irrigation should be practiced. Under polyhouse conditions the sprinkler/ drip irrigation system facilitates higher production of quality cut flowers. The plant has a requirement of 500-700 ml per day.

Weed Management

Weeds cannot be avoided in the green house as well as fields. They deplete moisture and nourishment from plants. Shortly after cuttings are established, carefully scratch the ground to uproot the weeds when they are small. 2-3 hand weeding is required for proper growth of the plant. First weeding should be done one month after planting. Weedicide can also be applied to control weeds from the field.

Common Diseases and their control measure

Powdery mildew (*Erysiphe cichoracearum*): The infection causes white powdery coating on the foliage. The plants should be lightly irrigated by drip irrigation system so that they can be protected by excessive humidity. Destroy the affected plants and the leaves. This disease can be controlled by spraying fenarimole (0.5ml /litre) or Dianocab (0.3 ml/litre).

Collar rot (*Phytophthora cryptogea*): The infection occurs just at the soil surface on the collar portion of the stem. In some cases the leaves turn yellow and the entire plant wilt. The disease can be controlled by drenching the soil in the root zone of the plants either with metalaxyl or with contact fungicide such as captan and copper oxychloride @ 0.2 mg/l.

Root rot

Several fungi namely *Phythium, Sclerotium rolfisii and Rhizoctonia solani* affect the root system of gerbera. Sterilizing the soil before planting and regular application of fungicide like copper oxychloride @ 0.2 mg/l to soil may help in controlling the disease.

Common pests and their control measure

Leaf miner

This insect makes zig-zag mines inside the leaves which lead to yellowing to browning of the leaves. The infected plants should be destroyed. Spray of Sypermethrin (0.5-0.75 ml/litre) or Dichlovos (0.5-1.8 ml/litre) controls the miner.

Aphid

The small, green coloured insects are present on the new twigs and the flower buds. They suck the sap of the plants and injure them. To control aphids, spray Metasystox (0.1%) and Parathion (0.02%).

Mites

These are small brown coloured insects which are normally not seen by naked eyes. They are located on the lower surface of the leaves. They suck the sap and brown spots appear on the leaves. In case of higher incidence of mites, web like structure is formed. The incidence is more on hot and dry areas. Mites can be controlled by spray of Indosulphan (2.0 ml/litre) or Dicophol (1.5 ml/litre).

Thrips

Thrips are brown coloured winged ants like very small insects. They suck the sap of soft twigs, flower buds and leaves which leads to dirty brown spots. Thrips can be controlled by spray of Indosulphan (2.0 ml/litre) or Dicophol (2.0 ml/litre).

Harvesting

Gerbera starts flowering 8-12 weeks after planting. Harvest 2 to 3 times a week. Stems are pulled not cut and the "heel"(base of the stem) is then removed to allow hydration. Freshly harvested cut gerbera stems can last from 2 to 3 weeks and cultivar differences in vase life can be extreme.

Postharvest Management of Gerbera

The stem of gerbera is highly prone to bending. The stem showing bending is not accepted well in the trade. The stem should not be less than 40 cm and should be firm and straight. The flower should be uniform in size which should not be less than 7 cm.

The flowers of gerbera are packed in flat boxes containing paper insert with holes for individual stems. The support is necessary to prevent the stems from moving. For domestic before packing the individual flowers can be inserted in polyethylene sleeves, to protect them from bruising.

Quality Requirements per Batch

The following additional requirements apply:

- Gerbera must be free of growth defects, including tears during growth and irregularly shaped hearts and flowers.
- Gerbera must be free of heels.
- The batch must have no limp flowers. The tolerances as shown in Overview 1 in the General Specifications for Cut Flowers apply.
- GRADING CRITERIA PER BATCH
- Gerbera must be graded according to:
- Ripeness.

- • flower diameter, whereby:
    - the flower is measured from the narrowest side of the flower and flat, meaning that by laying a ruler on the flower, it will be flattened a little bit. The measured diameter is rounded down in accordance with the overviews;
    - contrary to the General Specifications for Cut Flowers a tolerance of 0 does apply.
    - for flowers with a diameter of less than 9.5 cm, the difference between the largest and the smallest flower may not be more than 1 cm. For flowers with a diameter of 9.5 cm and more, the difference between the largest and the smallest flower may not be more than 1½ cm.
    - during trade the flower diameter grade may be mentioned in the grade code by using characteristics code S23. The diameter of the smallest flower, rounded down, is indicated.

Packing Requirements

General

- Gerbera with a minimum stem length of 40cm are packed in interior boxes.
- Gerbera with a stem length between 35 and 40 cm may be packed in interior boxes, provided that the minimum length is mentioned on the auction note and on the box.
- Gerbera with a stem length shorter than 35 cm may not be packed in interior boxes; they must be supplied standing in water.
- The interior fittings must be stapled to the inside of the box. There must be no risk of the stems moving in the box; the auction may to this end demand the use of a strip of foam rubber.
- For delivery in boxes Gerbera must first be pre-watered in clean water (with the recommended pre-treatment agents, if possible) and then packed dry.
- If Gerbera are delivered in bunches, then bunches of large-flowered Gerbera must consist of 10 stems and bunches of Gerbera mini of 25 stems, possibly with added Gerbera leaves.

Yield

The average yield under greenhouse is around 200 cut flowers/m^2/year of which 85% of I grade quality while it is 180-225 flowers/m^2/year under open condition with only 15-20% of flowers being if I grade.

Important tips and best practice for crop cultivation

- Always use double type varieties with black centre
- Shadenet ensuring 50% shade should be used for cultivating the crop

Marketing and distribution and transplanting:-

Gerbera has a good demand in cut flower arrangement, so can be marketed to major/ big cities where these can be supplied to hotel, Institutions, etc. Being sensitive to temperature, carnations must be transported using reefer vans for extended vase life. The flower are either transported in refrigerated van at 4-5^{0}C or percooled flowers are transported by the air.

Preventive Measures for Managing Diseases under Green House

R.P. Singh and Mohd. Nadeem Akhtar
Department of Plant Pathology, G.B.P.U.A&T., Pantnagar- 263 145 (UK)

The greenhouse climate is ideal for the development of plant diseases. An integration of cultural practices, environmental control, biological control, and natural control products will be needed to prevent widespread outbreak. Many fungicides are also toxic to beneficial organisms, and should be avoided if possible. Alternative disease control techniques include the use of disease resistant varieties, disease-free seeds and plants, well-drained soil, air circulation, weed eradication, humidity control, sanitation, disease-suppressive composts, compost watery extracts, and microbial antagonists.

The major emphasis of a plant disease control program for greenhouse vegetable production is on prevention. It is far more expedient to prevent the introduction of a plant pathogen than it is to control it once it is present. Disease prevention, like any other component of production, is hard work. As with all work tasks, it can be done either superficially or intensively. It is safe to say that the level of effort put into disease prevention will correlate with the level of yield obtained. An intensive and comprehensive disease prevention program is outlined below.

Preplant Sanitation for Disease Management

House Preparation.

After harvesting of the previous crop remove as much of the previous crop debris as possible. This debris must not be discarded in a dump pile adjacent to the production site because plant pathogens can overseason in plant debris. All houses should be cleaned of all fallen plant debris and surfaces cleaned free of soil, media, etc. Production systems that have had incidence of root and stem diseases should be rigorously sanitized. Passive solarization during the noncropping period in summer is veryn much beneficial. Structures can be sealed completely after wetting media, surfaces etc. The temperatures generated will assist in the eradication of pathogens and other pests in the production area.

All air intakes should be covered with insect-proof screens and soil-proof screens. Houses should be inspected for possible entry points of unsterile soil or insect vectors of plant viruses. Land adjacent to the production houses should be maintained by frequent mowing. Appropriate weed control is needed if weed population is high.

Media Preparation

Incidence of soil borne diseases should be carefully recorded. Infested bags or rhizosphere and adjacent soil should be discarded immediately after plant death. Infested media in troughs should either be discarded or sterilized. New media should be mixed upon disinfested concrete slabs to avoid exterior soil contamination. Trough structures should be thoroughly disinfested prior to being refilled. All troughs should be sterilized between crops depending on the house design, available sterilant products. In soil bed production system in the greenhouse soil should be solarized between cropping seasons.

Water Source

Where persistent soil borne diseases problems occurred even after sil sterilization, a possible source of infection may be irrigation water. Water from deep wells and tap water are usually free of this risk of pathogen intrusion. Also sump location should be checked, since surrounding land should be pitched away so there is no possibility of back flushing soil into the sump during heavy rains.

Tool and Surface Cleanup

Soil fungi can survive in dried soil on tools between seasons and certain viral and bacterial pathogens survive on hand tools between crops. Tools used for pruning, media transport, pollinating etc., should be disinfested between cropping seasons. Areas destined to contact tools or transplants should also be treated with a disinfestant.

Transplant Production

Transplant quality is extremely important for taking healthy crop.For the production of transplant only certified or disease free seed, protrays, and fresh sterile media should be used. Dropping one transplant onto unsterile soil can contaminate this plant with propagules of soilborne pathogens. Transplants should be produced in a separate greenhouse from ongoing crop production to minimize worker contact with these plants. Isolation of transplants will reduce the likelihood of disease spread from production areas.

Production Sanitation for Disease Management

Recommended sanitation steps that have been found successful in reducing the infection are given below:

1. To avoid the entry of wind-carried insects, soil etc directly from the outside in the production area, an 'air lock' type entrance to each production house is must.
2. Use of foot baths to prevent unsterile soil from being carried into the production space.
3. Restricted access by visitors to production and transplant houses.
4. Raising transplants at a height of at least 1 feet above the ground to minimize dust or splashing soil contamination of plants.
5. Prohibition of bidi, cigarette, and chewing tobacco use by workers involved in production areas, so as to minimize contamination by viruses present in tobacco.
6. Rigid hand-washing/scrubbing rules for personnel involved in pruning, pollinating, tying, or harvesting activities.
7. Filters on all air intakes to restrict air-blown soil and vector-insect entry.
8. Rigid vegetation control around the periphery of houses to avoid insect and pathogen buildup on weeds.
9. Periodic tool, pathway, and bench surface treatment with disinfestants.

Production areas should be examined for the initial symptoms of disease during routine crop maintenance activities. The earlier a disease is found and identified, the more effective removal of infected plant parts will be to stop or slow disease progress. For disease identification and suitable management options, growers should contact the nearest KVK or Govt. extension specialist or private agency that specialized in disease diagnosis.

Biocontrol of Foliar Plant Pathogens under Protected Cultivation

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

The world area under protected crops is 307,000 ha, with vegetables occupying 65% (200,000 ha) and ornamentals, 35% (107,000 ha), while in India it is approx 30,000 hectares. Insects and diseases are the major challenges under protected cultivation as it provides favourable environment conditions. The greenhouse environment presents a unique situation that makes conditions more favourable for foliar diseases especially powdery mildew, downy mildew and gray mould caused by fungi and bacterial diseases caused by *Xanthomonas* and *Pseudomonas.* Some of the conditions that favour diseases also favours the biocontrol agents for the management of foliar diseases. Biocontrol in greenhouses may have a greater potential because of the development of fungicide resistance in the pathogen; workers are at greater risk of fungicide exposure in the greenhouse as most fungicides require a re-entry period; fungicides have a longer residual activity; controlled environment of green houses favours the survival and growth of biocontrol agent; availability of limited number of registered fungicides; most of the fungicides can not be used due to pre-harvest period of most of the vegetables; environmental awareness and consumer concern due to the ill effect of the fungicides and for the production of organic and export oriented products; reduced area and high density of planting; safe, non-toxic to humans and animals and are rapidly biodegradable. Bio-pesticides currently represent about 1.5-2.0 % of the world pesticide market. However, the growth rate of bio-pesticide over the next ten years has been forecast at 10-15% annually in comparison to 2% of chemical pesticides. During the last ten years, over 80 biocontrol products have been marketed worldwide. A large of these has been developed for greenhouse crops. However, not all of these products are registered as biocontrol agents, but some are also marketed as plant growth promoters, plant strengtheners, or soil conditioners Most of these products are formulations of either of the fungi *Trichoderma, Ampelomyces* or the bacteria *Pseudomonas* and *Bacillus*. Because of the high value and emphasis on quality of greenhouse crops, a biocontrol agents should be recommended, if can perform with the consistency and efficacy as of fungicides.

The increased use of biological controls has led to a reduction in pesticide applications and leads to environmentally responsible, intensive crop production. The primary strategy of biological control for greenhouse plant diseases is to introduce fungal parasites to control disease causing fungi in the greenhouse environment so that pathogens are unable, or have a reduced ability to infect the plants. Research in developing biological controls for greenhouse crop diseases is ongoing and it is likely that more potential products of the biological control will be available in the near future for greenhouse diseases. Biocontrol agents should be used as preventative measures and/or in combination or alternating with compatible fungicides for the effective management of foliar diseases.

There is a growing demand for sound, biologically-based pest management practices. Recent surveys of both conventional and organic growers indicate an interest in using biocontrol products, suggesting that the market potential of biocontrol products will increase in coming years. Applications of diverse biological control strategies have been successful in the greenhouse industry and continue to increase. The Bio-pesticide Industry Alliance has formed and it is now actively promoting the value and efficacy of bio-pesticides. Clearly, the future success of the biological control industry will depend on innovative business management, product marketing, extension education, and research.

Commercial Products for biological control of foliar pathogens under protected cultivation

Bio-pesticide	Biocontrol organism	Target pathogen /disease	Crop	Formulation	Application method
AQ 10	*Ampelomyces quisqualis*	Powdery mildew	Cucurbits, grapes, tomatoes, ornamentals and strawberries	Spore powder	Spray
Sporodex	*Pseudozyma flocculosa*	Powdery mildew	Cucumber, tomato and rose	Spore powder	Spray
Plant Shield, Trichodex, Top shield	*T. harzianum*	Gray mould	Vegetables and ornamentals	Spore powder	Spray
Ketomium	C. *globosum and C. cupreum*	*Colletotrichum* leaf spot	vegetables	Spore powder	Spray
Cease	*Bacillus subtilis*	Anthracnose, gray mould powdery mildew and leaf spot (*Xanthomonas* and *Pseudomonas*)	Vegetables and ornamentals	Spore suspension	Spray
Serenade	*Bacillus subtillus*	Powdery mildew, downy mildew, *Cercospora* leaf spot, Early and late blight	Cucurbits, grapes, vegetables and ornamentals	Spore powder	Spray
Bio-save	*Pseudomonas syringae*	Gray mould	Ornamentals and vegetables	Pellets (bacterial cells)	Spray
Blight Ban	*Pseudomonas fluorescens*	*Erwinia amylovora* and russet inducing bacteria	Strawberry and tomato	Wettable powder (bacterial cells)	Spray
Mycostop	*Streptomyces griseoviridis*	gray mould, *Alternaria* and *Phomopsis* leaf spot	Ornamentals and vegetables	Spore powder	Spray
Actinovate	*Streptomyces lydicus*	Powdery mildew, downy mildew, gray mould, *Alternaria* leaf spot	Vegetables and ornamentals	Spore powder	Spray

Compost: Its Microbiology and Disease Management

C.M. Mehta and A. K. Sharma
Department of Biological Sciences, C.B.S.H., G.B.P.U.A.&T. Pantnagar- 263 145 (UK)

Compost is organic matter that has been decomposed and recycled as a fertilizer and a key ingredient in organic farming. Composting is a biological process in which various organic biodegradable wastes are converted into hygienic, humus rich product (compost) which could be used as a soil conditioner and an organic fertilizer (Popkin, 1995). Composts of various origins are also used to provide biological control against various plant pathogens (Hoitink and Grebus, 1994). The addition of composts to agricultural soils has beneficial effects on crop development and yields by improving soil physical and biological properties (Zheljazkov and Warman, 2004). Poultry manure application in *Java citronella* plants, significantly increased the herbage, essential oil content and dry matter yield (Adholeya and Prakash, 2004). Compost is also an inhabiting place for various microbes due to which biological activities are markedly enhanced in the rhizosphere of plants (Tilak and Reddy, 2006). Such syntrophic associations are of ecological importance with implied agricultural significance. Aqueous extracts of compost have also been efficient in replacing synthetic fungicides (Zhang *et al.,* 1998). Utilization of compost with disease suppressive properties is a relatively new biological way of decreasing stress in plant production.

Steps Involve in Composting Process

Composting process involves four different steps viz., (a) Decomposition: breakdown of plant and animal remains into stable organic materials, (b) Humification: conversion of organic matter into humus (resistant to microbial attack), (c) Immobilization: microbial tie up of inorganic molecules into their own cells and (d) Mineralization: microbial release of inorganic ions (nutrients like nitrate, ammonium and phosphate).

Types of Composting

There are three different types of composting, according to its nature. First is Aerobic composting, where air directly involve in composting process. In this process, high nitrogenous waste (like grass clippings or other green material) helps bacteria to grow and create high temperatures (up to 160 degrees). This result, break down of organic waste quickly and is not prone to smell. This type of composting requires high maintenance, since it needs to be turned every couple days to keep air in the system and temperatures up. It is also likely to require accurate moisture monitoring. This type of compost is good for large volumes of compost. Second is Anaerobic composting where composting process completed without air. Anaerobic composting is low maintenance but this process took a couple years. In this type of composting a pile was made by stack of debris. It generally compact to the point where there is no available air for beneficial organisms to live. Very slow working bacteria grow in these piles that do not require air. It may take years to break down of raw material in compost. Anaerobic composts create the awful smell. Third is Vermicomposting which is most beneficial for composting food waste. Along

with red worms, this includes composting with bacteria, fungi, insects, and other bugs.

Different Phases of Aerobic Composting

Most commonly used aerobic composting process involves three different phases. First Mesophilic phase with moderate temperature, lasts for a few days, second Thermophilic phase with high temperature, lasts from a few days to several weeks and final Curing and maturation phase with moderate to ambient temperature, lasts 1-2 months (Fig. 1). This whole process of composting is carried out by involvement of different microbes. The initial process is carried out by mesophilic microorganisms followed by the decomposition of raw material by the involvement of thermophilic microorganisms. These include fungi, bacteria and actinomycetes (Hultman, *et al.,* 2010; Partanen *et al.,* 2010). Once the readily degradable materials are degraded, the reaction rate slows down. Eventually the temperature decreases once again to the mesophilic range through heat loss from the surface of the heap and again the mesophiles, either through re-invasion from outside or through germination of heat resistant spores, dominate.

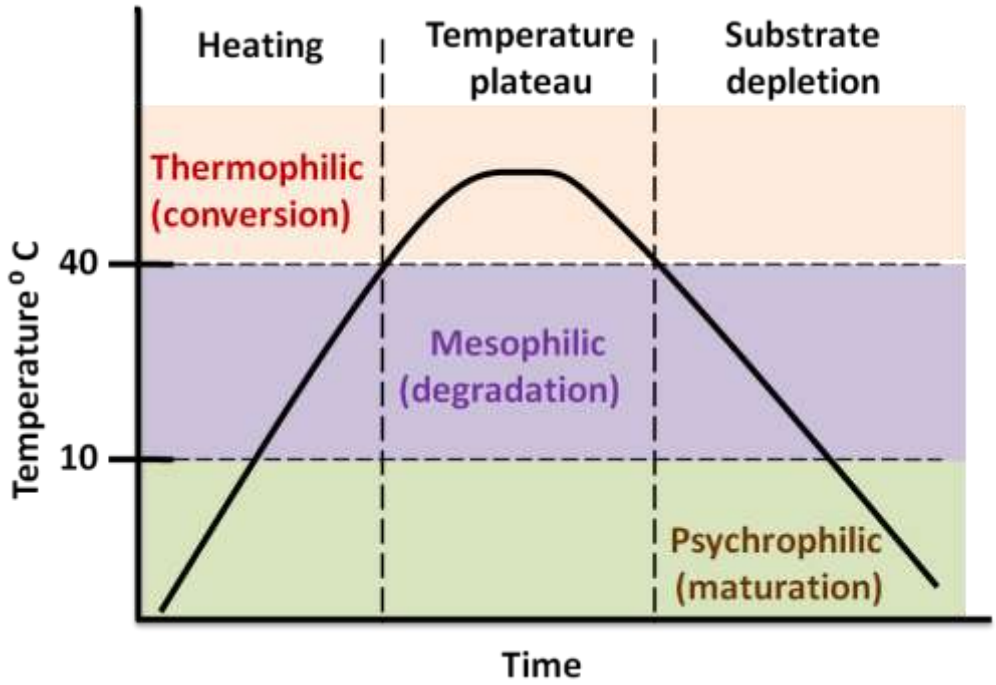


Figure 1: Composting process and its different phases

Compost Microbiology

Bacteria, fungi and actinomycetes are the three major groups of microorganisms largely responsible for most of composting process. Bacteria are the smallest living organisms and the most numerous in compost; they make up 80 to 90% of the billions of microorganisms typically found in a gram of compost. Bacteria are responsible for most of the decomposition and heat associated with composting. Bacteria don't have to be added to the compost. They are present virtually everywhere, and enter the pile on every single bit of organic matter. Many types of bacteria participate in the composting process, thriving at different temperatures and on different materials. Mesophilic bacteria break down soluble, readily degradable compounds (sugars,

starches). Thermophilic bacteria break down proteins, fats, cellulose, hemicelluloses. Psychrophiles are aerobic bacteria that thrive in low temperatures of approximately 55 degrees Fahrenheit and slowly decompose compost even at 0 degrees Fahrenheit.

Actinomycetes the second major group present in compost, are filamentous bacteria without nuclei, but they grow multicellular filaments like fungi. Actinomycetes form long, thread-like branched filaments that look like gray spider webs stretching throughout compost, and give the pile a pleasing earthy smell. In composting they play an important role in degrading complex organics such as cellulose, lignin, chitin, and proteins. Their enzymes enable them to chemically breakdown tough woody materials.

The third major group of microorganisms present in compost is fungi that include molds and yeasts. Most fungi are classified as saprophytes because they obtain nutrients from dead plant matter. In compost, fungi are important because they break down tough debris, enabling bacteria to continue the decomposition process once most of the cellulose has been exhausted. Fungi species are numerous during both mesophilic and thermophilic phases of composting.

Including all these microbes, earthworm, millipedes, nematodes and protozoa also play important role in composting. Earthworms play an important role in breaking down organic materials and stabilizing vermi compost. They are constantly tunneling and feeding on dead plants and decaying insects during the daylight hours. Their tunneling aerates the compost and enables water, nutrients and oxygen to filter down. They coat organic materials with a mucus-like film that binds small particles together and protect nutrients from leaching.

Compost and Disease Management

Composts have long been known to improve soil fertility and plant diseases management. Previously it has been shown that components of composts improve the ability of plants to resist disease caused by root pathogen like *Fusarium, Phytophthora, Pythium, Rhizoctonia* etc. and foliar pathogens like *Pseudomonas, Colletotrichum, Xanthomonas* etc.

Among soil borne root pathogen, suppression of *Fusarium* using composts has been reported by several researchers (Punja *et al.,* 2002). The severity of various diseases caused by *Fusarium* has been reduced between 20- 90% using compost amendments. Microbial activity has been considered a key factor in suppression of *Fusarium* wilt. Composts increased microbial populations and microbial activity in composts and composted peat mixes increased by 50% (Cotxarrera *et al.,* 2002). Several microorganisms or biocontrol agents have been isolated from composts or shown to contribute to suppression of *Fusarium* spp. including populations of non-pathogenic strains of *Fusarium oxysporum* and fluorescent *Pseudomonas* spp. (Kannangara *et al.,* 2000); *Trichoderma* and *Flavobacterum* (Hoitink and Fahy, 1986).

Phytophthora is another soil-borne pathogenic fungus that causes a variety of problems including root rot, a form of “dieback”; crown rot; or *Phytophthora* blight of plants. Composts have been used successfully for suppression of *Phytophthora* crown and root rots of nursery and fruit

crops produced in container media (Aryantha *et al.,* 2000) and field soils (Downer *et al.,* 2001). Addition of compost serves two possible purposes significant for the biological control of *Phytophthora cinnamomi*: it provides a substrate for the growth of fungal antagonists, and creates an environment that promotes enzyme activity (Downer *et al.,* 2001). Several potential biocontrol agents of *Phytophthora* root and crown rots have been identified from compost amended growing media, including *Pseudomonas* spp. (Aryantha *et al.,* 2000); *Pantoea* spp (formerly *Enterobacter* spp) (Krause *et al.,* 2003); *Penicillium* and *Aspergillus* spp. (Downer *et al.,* 2001); actinomycetes (Aryantha *et al.,* 2000) and *Trichoderma* spp. (Downer *et al.,* 2001).

Pythium is also a destructive, soil-borne parasitic root fungus, which causes damping-off disease in seedlings and root and crown rot of plants. The suppression of diseases caused by *Pythium* spp. has been well documented (Stone *et al.,* 2003). The severity of diseases caused by the fungus *Pythium* was reduced by 30-70% when growing media were amended with various compost products. Adequately mature composts have large microbial populations and high microbial activity, which have been directly linked to the suppression of *Pythium* (Ringer *et al.,* 1997) but this may not hold true for all composts (Craft and Nelson, 1996).

Similarly, *Rhizoctonia* is a soil-borne pathogenic fungus which causes a range of soil-borne diseases as well as diseases of aerial parts of plants. Composts have been used with varying success to suppress *Rhizoctonia* diseases of several crops (Tuitert *et al.,* 1998).Amendment of soil or container media with composts reduced diseases caused by the soil-borne pathogenic fungus *Rhizoctonia* by up to 70%. Higher levels of microbial biomass and microbial activity have been reported to suppress *Rhizoctonia* by increasing competition between compost-inhabiting microorganisms and *Rhizoctonia solani* (*R. solani*) for cellulose or other available nutrients (Diab *et al.,* 2003). The increase in microbial count (MBC) and microbial number (MBN) indicated growth of saprophytic microorganisms. The high population density of fluorescent pesudomonads, actinomycetes and heterotrophic fungi in growing media amended with adequately matured compost has been found to better suppress *Rhizoctonia* spp. than the use of less matured (immature) composts (Diab *et al.,* 2003).

Composts are considered able to induce systemic resistance, which can reduce the severity of some plant foliage diseases (Stone *et al.,* 2003). However, Krause et al. (2003) reports that only a small proportion of composts have the ability to suppress foliar diseases. Some pathogenic *Pseudomonas* species cause several plant foliar diseases including bacterial speck and bacterial canker. Compost application has resulted in reduced bacterial speck of Arabidopsis (mustard family) and tomatoes. In tomatoes, different types of paper mill residue based composts resulted in the reduction of bacterial speck between 47 to 62% (Vallad *et al.,* 2003).

Similarly pathogenic *Xanthomonas* spp. causes many plant diseases, including such foliar diseases as bacterial leaf spot or speck, bacterial blight or angular leaf spot, and stem rot. Two studies report a reduction in bacterial leaf and fruit spot of vegetables (radish and tomato) caused

by *Xanthomonas* spp. (Krause *et al.,* 2003). Abbasi *et al.* (2002) found that, in tomato production, application of composted garden organics resulted in reduced bacterial spot incidence on fruit by 28-33%, although the severity of disease on foliage was increased. *Bacillus* spp. has been identified as most effective in suppressing bacterial leaf spot (Krause *et al.,* 2003).

Some fungi like *Colletotrichum* also cause foliar diseases such as anthracnose fruit rot or lesions. Research has shown that amendment of soil or container media with composts can reduce the severity of anthracnose (Abbasi *et al.,* 2002). Composted cannery waste applied at a high rate (24-30 t ha^{-1}) reduced the incidence of anthracnose in organic tomatoes by 40% (Abbasi *et al.,* 2002).

These studies indicate that compost amendments play a valuable role in reducing disease. However the variability among composts makes it difficult to frequent use of composts in agriculture field. In future a lot of study is needed to understand the role and mechanism of compost against plant diseases so that a strategy can make to minimize the compost variability. In future attentions also needs to be paid to non culturable members of the root associated and soil communities because these microorganisms may be numerically dominant and have not been studied. Molecular methods developed for the study of microorganisms in their environments are key tools for the study of the influences of the microbial community on biocontrol and also in the future there is need to understand the mechanism behind the compost based disease suppression.

REFERENCES

- Abbasi, P.A., Al-Dahmani, J., Sahin, F., Hoitink, H.A.J. and Miller, S.A. 2002. Plant Dis. 86: 56-161.
- Adholeya, A. and Prakash, A. 2004. Bioresour Technol. Tanu., 92: 311–319.
- Aryantha, I.P., Cross, R. and Guest, D.I. 2000. Phytophthology, 90: 775-782.
- Cotxarrera, L., Trillas-Gay, M.I., Steinberg, C. and Alabouvette, C. 2002. Soil Biol. Biochem., 34: 467-476.
- Craft, M. and Nelson, E.B. 1996. AEM, 62: 1550-1557.
- Diab, H.G., Hu, S. and Benson, D.M. 2003. Phytopathology, 93: 1115- 1123.
- Downer, A., Menge, J.A. and Pond, E. 2001. Phytopathology, 91: 847-855.
- Hoitink, H.A.J. and Fahy, P.C. 1986. Ann. Rev. Phytopathology., 24: 93-114.
- Hoitink, H.A.J. and M.E. Grebus, 1994. Compost Sci. Utilization, 2: 5–12.
- Hultman, J., Vasara T., Partanen, P., Kurola, J., Kontro M.H., Paulin, L., Auvinen, P., Romantschuk, M. 2010. J. Appl. Microbiol. 108:472-487.
- Kannangara, T., Utkhede, R.S., Paul, J.W. and Punja, Z.K. 2000. Can. J. Microbiol. 46: 1021-1028.
- Krause, M.S., De Ceuster, T.J.J., Tiquia, S.M., F.C., M.J., Madden, L.V. and Hoitink, H.A.J. 2003. Phytopathology. 93: 1292-1300.
- Partanen, P., Hultman, J, Paulin, L., Auvinen, P., Romantschuk, M. 2010. BMC Microbiology 10:94.

- Popkin, R. 1995. Environ. Prot. Agency J., 21: 188–90.
- Punja, Z. K., Rose, S. and Yip, R. 2002. International Organisation for Biological and Integrated control of Noxious Animals and Plants (OIBC/OILB), West Palaearctic Regional Section (WPRS/SROP), Dijon, France, 25, pp 93-96.
- Ringer, C.E., Millner, P.D., Teerlinck, L.M. and Lyman, B.W. 1997. Compost Sci. Util., 5: 6-14.
- Stone, A.G., Vallad, G.E., Cooperband, L.R., Rotenberg, D., Darby, H.M., James, R.V., Stevenson, W.R. and Goodman, R.M. 2003. Plant Dis., 87: 1037-1042.
- Tilak, K.V.B.R. and B.S. Reddy, 2006. Curr. Sci., 5: 642–644.
- Tuitert, G., Szczech, M. and Bollen, G.J. 1998. Phytopathology, 88: 764-773.
- Vallad, E.G., Cooperband, L. and Goodman, R.M. 2003. Physiol. Mol. Plant Pathol., 63: 65-77.
- van Loon, L.C., Bakker, P.A.H.M. and Pieterse, C.M.J. 1998. Ann. Rev. Phytopathology, 26: 379-407.
- Zhang, W., Han, D.Y., Dick, W.A., Davis, K.R. and Hoitink, H.A.J. 1998. Phytopathology, 88: 50–455.
- Zheljazkov, V.D. and P.R. Warman, 2004. J. Environ. Qual., 33: 542–52.

Protected Cultivation Technology-The Developmental and Innovative Perspective

Sanjai K Dwivedi
Defence Reserch and Development Organization (DRDO), CEPTAM, Metcalfe House, Delhi-110054

Protected cultivation technology tempts one's mind as it permits enormous modification in microclimate enabling the cultivation of crops in adverse climatic conditions, caring least for the outside environment. Vrikshayurveda, an epic of 11th century AD by Surapala, states that any plant/tree could be grown anywhere provided king, treasury and destiny are favourable. This is an indication that agricultural experts of that era were aware of the protected cultivation methods. The idea of growing plants in environmentally controlled areas has also existed during Roman times. The Roman emperor Tiberius ate a cucumber-like vegetable daily. The Roman gardeners used artificial methods (similar to the greenhouse system) of growing to have it available for his table every day of the year. Cucumbers were planted in wheeled carts which were put in the sun daily, then taken inside to keep them warm at night. The first modern greenhouses were built in Italy in the thirteenth century to house the exotic plants that explorers brought back from the tropics. They were originally called giardini botanici (botanical gardens). The concept of greenhouses soon spread to the Netherlands and then England. Jules Charles, a French botanist, is often credited with building the first practical modern greenhouse in Leiden, Holland to grow medicinal tropical plants. In the nineteenth Century the largest greenhouses were built. The conservatory at Kew Gardens in England is a prime example of the Victorian greenhouse. In Japan, the first greenhouse was built in 1880 by Samuel Cocking, a British merchant who exported herbs. In the Twentieth Century the geodesic dome was added to the many types of greenhouses (Anon, 2008). In the country like India with its vast and diverse agro-climatic conditions, protected cultivation technology in the last three decades has made good progress and proved as a boon for production of high value, low-volume crops with better productivity and quality.

Uses

Greenhouses are often used for growing flowers, vegetables, fruits, and other plants. Many vegetables and flowers are grown in greenhouses in late winter and early spring, and then transplanted outside as the weather warms. Started plants are usually available for gardeners in farmers' markets at transplanting time.The closed environment of a greenhouse has its own unique requirements, compared with outdoor production. Pests and diseases, and extremes of heat and humidity, have to be controlled, and irrigation is necessary to provide water. Significant inputs of heat and light may be required, particularly with winter production of warm-weather crops. Special greenhouse varieties of certain crops, like tomatoes, are generally used for commercial production. Greenhouses are increasingly important in the food supply of high latitude countries. One of the largest greenhouse complexes in the world is in Almeria, Spain where Greenhouses cover almost 50,000 acres (200 km^2) and where almost 5% of Spain's salad vegetables are grown.

Greenhouses protect crops from too much heat or cold, shield plants from dust storms and blizzards, and help to keep out pests. Light and temperature control allows greenhouses to turn inarable land into arable land. Greenhouses can feed starving nations where crops can't survive in the harsh deserts and Arctic wastes. Hydroponics can be used in greenhouses as well to make the most use of the interior space. Biologist John Todd invented a greenhouse that turns sewage into water, through the natural processes of bacteria, plants, and animals (Anon,2008).

2. Greenhouse Technology

Greenhouse technology implies production of plants for economic use in covered structure that allows rapid harvesting of solar radiation and modification of agro-climatic conditions conducive for plant growth and development. The technology embraces infrastructure modelling, selection of plants for adaptation, production economics, agronomic management and commercial potential etc.

“A greenhouse is a framed or an inflated structure covered with a transparent or translucent material which permits at least partial control of plant environment and which are large enough to permit a person to carry out cultural operations” (Chandra and Panwar, 1987). While full advantages is taken of the available sunshine for crop production by way of selecting proper covering materials, the enclosure provides an opportunity to control the other environmental parameters. As a result greenhouse crop productivity is largely independent of outdoor environmental conditions. However, environmentally controlled greenhouses are not popular in Hilly region simply because of acute shortage of electric power in the region. Hence, greenhouse technology is discussed with special emphasis on crop production in Hilly region. Types and design of protected structures mainly depend on the availability of materials, purpose of protection, climate of the region and market for quality produce. Environmental conditions in general include light, temperature, air composition and nature of root medium. Depending upon the local climate and crop requirements, adequate environmental control is attempted rather than full control of fall components to maximize the profit.

2.2 Principle

A greenhouse is generally covered with transparent material such as polyethylene, glass or polycarbonate. Depending upon the clading material and its transparency major fractions of sunlight is absorbed by the crops and other objects. These objects in the greenhouse in turn emit long wave thermal radiation for which cladding material has lower transparency with the result solar energy is trapped and resist the temperature inside the greenhouse (Nimje and Shyam, 1991). This is known as greenhouse effect. This rise in temperature in greenhouse is responsible for crop forcing in adverse climate. During winter month’s loss of trapped temperature should be minimised whereas, during summer months air temperature in greenhouse is to be brought down

by providing cooling device or ventilation.

2.3 Agro-climate

There are several climatic factors that need care in the management of a green house. The following factors are important for greenhouse cultivation.

a) Sun Light

The direction of the greenhouse should be such that it receives sunlight for maximum hours. In hilly region, greenhouse should face south - East direction and its location should not be under shade. However, the tropical condition temperature retention can be reduced by choosing a less sunny site. Sun light is essential for augmentation of the process of photosynthesis and minimum sun requirement of crop should be kept in mind. In addition, sunlight also provides requisite thermal environment for various other physiological processes including photosynthesis. Hilly regions receive clear sunny days in winter so sunlight as such may not be limiting factor but its tapping and conservation could be a major concern for further investigation.

b) Temperature

Sunlight is the major rather sole source of temperature. Examples of providing external heat source other than sunlight are rare in Hilly region. Temperature during night hours may drop down to below zero degree Celsius of heat obtained from trapped solar radiation is not properly conserved. Following steps are advantageous to maintain thermal environment of greenhouse.

i. Blackening of internal surface of brick wall and soil bed surface.
ii. Providing insulation by doubling brick wall.
iii. Covering polyethylene or glass external surface with multi layer covering during night hours.
iv. Mud plastering in case of stone walls.
v. Placing of black coloured stones in the green houses.
vi. Keeping containers filled with water.

c) Relative humidity

The minimum limit of relative humidity for normal physiological functioning of the plants is 50%. Extreme xeric conditions hardly allows relative humidity to rise to this level in outer environment but inside greenhouse sufficient water application and restricted air circulation gear up and maintain relative humidity at higher level. It may be increased by keeping pan evaporation. Mechanical device which automatically controls relative humidity by periodical sprinkling of water. Cooling pads are ususlly installed in low humidity and tropical areas.

d) CO2 Enrichment or Maintenance

Carbon dioxide (CO2) is the basic ingredient required for manufacturing of organic matter by process of photosynthesis. In cold arid region CO2 concentration is below normal (NAEDB, 1992) and in the closed structure like green hosues it may drop down further because of its consumption by the plants. At relatively high sunlight intensities and temperature photosynthetic

rate is directly proportional to CO_2 concentration upto 2400 ppm. Hence supplementary application of CO_2 will boost plant productivity inside the greenhouse. Under Hilly region situation., appropriate air circulation is better and economic means to prevent undesirable lowering of CO_2 while for conservation of CO_2 produced at night, a tight closed greenhouse is pre requisite.

e) Soil

Soil serves as growth medium for plants. Sandy loam soil is the best choice. It should be supplemented with well rotten FYM, compost or biofertilizers. Inorganic fertilizers need to be used as per recommendations. Continuous cultivation inside the greenhouse may give rise to pathogens. To destroy pathogens pasteurization of soil is recommended (steam aeration) before every crop and soil replacement is recommenced after every 3 years. For steam aeration temperature of 60°C for 30 minute is good enough to accomplish the task. Chemical fumigation can also be used but steam is the best as it is not selective thus attacking all sort of pathogens.

2.4 Benefits of Greenhouses

Major benefits of greenhouse in are given below:-

i. Cultivation of crops during off season when it is not possible to grow in open fields.
ii. Tropical vegetables like cucurbits, capsicum, brinjal, okra etc are rare in hilly region but these crops can be grown in greenhouse.
iii. Greenhouse provides an excellent opportunity to produce quality crops for export.
iv. Raising nursery earlier and advancing the availability is also possible by use of greenhouse.
v. Productivity in greenhouse is increased manifold in comparison to open field.
vi. Conservation of valuable planting materials and its cultivation is also possible under greenhouse.
vii. Greenhouse can also be used for growing of flower plants, strawberries, grapes and propagation of quality fruit plants.
viii. Insect pest and weed management is easier in greenhouse than open.
ix. Greenhouse conserve the moisture. Hence frequency of watering to plants get reduced.
x. Greenhouse is ideally suited for Indian farmers having small holdings.
xi. Productivity per unit area and time can be increased by adopting suitable crop sequences.

3. Infrastructure of Greenhouse

3.1 Types of Glazing Materials

3.1.1 Glass

Glass has been the preferred covering material for greenhouse world wide becuase of its light transmissivity characteristics. Transmissivity of 40-50 years old glass differs a little from that of new glass. Temperature retension in glasshouse is pretty good. However, high installation cost is major limitation. Moreover, transportation of materials and frequent damage of glasses due to

high wind velocity, glasshouse is discouraged.

3.1.2 Polyethylene

Plastic polyethylene is the most widely used greenhouse film around the globe. It is produced by mixing homopolymers of ethylene with or without an ultra-voilet (UV) inhibitor package but only UV stabilized polyethylene sheet is only recommended because non UV inhibitor package added polyethylene will break down after 3-5 months due to photochemical reactions. Polyethylene film is tough, flexible and relatively in expensive. It can withstand as low as -50°C but 80-90°C temperature will cause it to melt. Above 60°C it losses much of its strength and may stretch markedly. The life of UV stablized polyethylene film is 1-3 years. However, regidex polyethylene sheet may be used for 5-6 years on trench.

3.1.3 Fibreglass Reinforced Panel(FRP)

These panels consist of glassfibre reinforced polyester. The panels have been very popular in areas of high light intensity such as southern USA but about 10-15% heat loss due to increased exposed area makes it unfit for most of Indian region region. Further, with its age under use, the transprency get reduced due to yellowing.

3.1.4 Polycarbonate Panels.

The panels are available in double skinned sheets. SDP polycarbonate sheets are similar in physical dimension to the SDP acrylite but are stronger and have a lower light transmissivity. Its price is approximately 25% higher than SDP acrylite.

3.2 Construction Materials

Besides glazing materials (Polyethylene/glass) several other materials are also requires for construction of a greenhouse. It is always better to prefer the use of locally available materials for the construction of a greenhouse. It not only reduces the installation cost but also help to popularize the technology. The major construction material required for greenhouse is its frame structure which could be either of a metal or wooden. Iron angle, GI pipes or alumminium frame are the most common metal used in greenhouses. Wooden frames can also be used which are locally available in the region. Such frames are cheaper than those of metal frames and also easy to use. Wooden frame should also be preferred in hilly regions since metal is a good conductor of heat thus its temperature get reduced during winter months during summer it gets hot and polyethylene sheet gets stuck to metal which tears off the sheet. Sometimes supporting wares are also used in greenhouse to hold the polyethylene sheet. It is always advisable to avoid direct contact of metal with polyethylene sheet. If at all it is essential, gunny bags or cloth should be wrapped over the metal. Other precautions include use of smooth surfaced frame and removal of sharp edges of frame. Strong foundation of frame is essential in cold arid region to resist the strong winds. Stability is further ensured by constructing earthern brick wall at the back and on

either side.

4.0 Types of Greenhouses

Various types of greenhouses are also seen in India. The brief description of each type is being discussed below.

4.1 Glasshouse

As its name indicates, glass is used as glazing material in this greenhouse. Perhaps this is the first and oldest among all types of greenhouse structures. Glass panels are fitted with the help of wooden or metal frame. It can be of any shape and size and it is pretty effective for winter cultivation but due to increase in day temperature in summer, it becomes unfit for cultivation during summer. High initial cost, difficulty in construction and frequent damage of glass panels by strong winds are other discouraging factors. In Hilly region only a few such structures are found that too for research. One oldest glasshouse constructed in 1964 is available with FRL-Leh.

4.2 Polyhouse

Ideal features of polyethylene have increased the use of polyhouses inplace of glasshouse throughout the globe. It has not only reduced the initial cost but also increased the popularity of greenhouse by simplifying the installation technology. Generally two type of polyhouses are there in Hilly region.

4.2.1 Prefabricated polyhouses

A prefabricared metal structure of convenient size is installed and polyethylene film is covered over it. This structure is not recommonded at all for the region because of poor temperature retension, low crop yield and high installation cost (Singh, et. al; 1998).

4.2.2 Ladakhi polyhouse

This is one of the innovative and low cost greenhouses of Ladakh region. It is similar to normal but the only difference is its surrounding mud brick wall in place of polyethylene sheets which not only cut down the installation cost but also reduce the adverse affects of strong winds and also increase temperature retention and ultimately net profit get increased. This is generally lean type, have three sides made of mud bricks. The back wall is 7 ft in height, while front has no well. The length is 32 ft with a width of 16 ft (Singh et al,2000). The polyethylene is supported on wooden poles and side walls. The two side walls one descending towards the front. J&K State Deptt of Agriculture/ Horticulture provides cash subsidy besides 32 x 16 ft free polyethylene sheet. This has brought boost to greenhouse revolution in Ladakh.

4.3 Trench (Underground greenhouse)

This is an unique, innovative and very simple, cheap and useful underground greenhouse structure for Hilly region and thus has unlimited potential in the region. This may be of any convenient dimension. However, a trench of 30 x 10 x 3 ft size is ideal. In this pit type of structure, wooden poles are used to hold UV stabilized polyethylene film. The polyethylene is also covered by an additional or woolen or cotton sheet polyethylene film during night to reduce the

heat loss during extreme winter. The damage of blowing off the polyethylene film by strong winds is minimised by putting stones along the sides. Cultural practices and other operations are done by removing polyethylene sheet from top of the trench. The structure does not require much skill in its construction and management. Its cost is lowest among all other greenhouses and being an underground structure heat loss is minimal and temperature retention is high (Singh and Dhaulakhandi 1998) and thus yields good crop. Strong winds does not affect polyethylene cover much and hence it is long lasting. This structure is therefore, being recommended as most suitable greenhouse for the region (Singh et. al; 1998 &2000).

4.4 Plastic Low Tunnel

It is a small semi sphereical structure frame made of metal, wood or plastic and covered with polyethylene or fiber reinforced plastics to create protected environment. Plastic low tunnels are flexible transparent coverings that are installed over rows of individual beds of transplanted vegetables to enhance the plant growth by warming the air around the plants (micro-climate) in open field during winters. These help in warming the soil and protect the crop against the hails and snow and advance the crop by 30-60 days than their normal season. This low-cost technology is very simple and highly profitable for off-season cultivation and catching the early market. Generally galvanized iron arches are fixed manually 1.5-2.0 m apart to support the plastic tunnel. Width and height is kept about 45-60 cm to cover the plant as per the crop requirement. Transparent non-perforated plastic of 30-50 thickness is sufficient. It partly reflects infrared radiation to keep the temperature of low tunnel higher than outside. Small vents can be made at the side of tunnel to facilitate proper aeration in tunnel.These structures serves as mini greenhouse. This is a temporary structure which can easily be shifted to any place. However, major problem in tunnels is faced in watering, weeding and harvesting which involves removal of cover and again putting them back.

4.5 Double Wall Polyench

A structure designed by FRL, Leh, to harness the soil and solar heat for growing the vegetables especially during winter months. The polyench refers to a polyhouse erected over a trench where back and sidewalls are made up of mud bricks. The sidewalls are provided with double walls filled with insulating material available locally i.e., sawdust for better retention of heat inside the polyench. The inner walls are painted black to absorb more solar radiation during morning hours. The structure is also like gable uneven span with modified roof having polythene sheet towards sun facing side and grass thatch support over wooden frame opposite to sun facing side with provision of ventilators in the roof. Since locally available material has been used in this greenhouse, the cost is reduced drastically compared to normal greenhouse with better efficiency of temperature retention than trench and polypouse. Considering the wear and tear occurred due to high wind velocity in the Hilly regions, the polythene sheet has been replaced with FRL sheets to increase the life span of the structure. The structure has been accepted by the Ladakh

Autonomous Hill Development Council (LAHDC) and state Govt is providing subsidy of 50 per cent to the farmers for promoting the protected cultivation in Ladakh region.

4.6 Multipurpose Nets

Shade nets are used to reduce the adverse effect of scorching sun and heavy rain. Shade houses are becoming popular for growing crops and nursery during summer season. Net houses are used for raising vegetables/fruits/flowers/medicinal plants in high rainfall regions. Roof of the structure is covered with suitable cladding material mostly HDPE, which does not absorbs moisture. Slides are made of wire mesh of different gauges 25-90 percent shade depending upon requirements. Such structures are popular in north-eastern region of the country.

Similarly weed nets are made of HDPE and covered on ground to control the weeds by reducing light on the soil. Insect proof nets are effective to reduce the incidence of number of pests and viral dieses in crops. These nets are used like mosquito net around the crops, having 40-50 mesh size. Other similar nets include bird protection nets to control the bird damage of plats/crops, hail protection nets and reflector nets etc.

6.0 Features of an ideal greenhouse

Peculiarity of region's weather i.e very high day-night temperature fluctuations strong winds and high light intensity coupled with UV radiation etc must be kept in mind anddesign should be done as per the needs for the region. Since hilly regions are remotely located and isolated from main land hence all the required materials for greenhouse must be locally available and cheap in cost so that poor farmers can afford the expenditure. The greenhouse must be capable enough to trap the solar energy and produce the crops even at subzero temperatures (Tewari and Dhiman, 1986). It should also be strong enough to resist the snow load, strong cold waves and extremely low temperature. The structure in hills should be also be able to retain the temperature for longer period besides being simple and easily manageable so that even a lay man can built and manage it without any difficulty. All the features may not be accommodated in one type of greenhouse (Singh et. al; 1998 a).

7.0 Selection of Suitable Crops and Production Technology for Greenhouse

Selection of crops for production in green house is the most important factor in success. The crop should not only be able to tolerate the low winter temperature but should also grow under the cover where very little and diffused sun light is available. Fast vertical growing and ratoon yielding crops should be prefered so that horizontal and vertical space is fully utilized, more number of cutting/harvesting can be taken. Root crops like radish, beetroot, carrot, turnip can also be grown (Singh et al, 1997).A list of vegetables suitable for winter months, their recommended varieties, sowing time and planting distance is given in Table-5 (Singh, 1995 b). Among all, most important factor is sowing time. Even one day delay in sowing causes significant reduction in yield. Thus crop should be sown before onset of winter which enable the plants to resist low temperature.

There are certain other managemental tips required to be adopted for green house cultivation which are listed below :-

Use of well rotten FYM @1.5-2.0 Kg per m2 atleast 30 days before sowing improves the growth and yield of crop. Use of chemical fertilizer is generally avoided. However, 10-12 g of DAP per m2 before sowing and 5-7 g perm2 urea enhance the growth of plants.

i. Since every bit of soil under cover is highly precious, hence it should be utilized properly. Even ridges of beds and channels should be used for growing of the crops.
ii. Water soaking of seeds for 36-48 hours before sowing results faster and higher germination percentage. Soon after sowing light irrigation is benefitial.
iii. Frequent light irrigation has been recommended for winter cultivation. It not only enhances the crop growth but also improves low temperature tolerance of the plants.
iv. Since greenhouse temperature falls down below zero degree celcius during peak winter months, cold protection measures are essentially required for crops growing under the cover. For this, one additional covering of polyethylene just two fts above the plants (inside greenhouse) has given encourging results. This improves microclimate around the plants and hence crop growth gets increased. This covering is required especially during night in the month of December and January. Depending upon environmental temperature and sunlight, the polyethylene film may be removed during day time.

9.0 Future Thrust

Greenhouse technology development has made good progress in India during last two decades and steps necessary for promoting greenhouse cultivation of vegetable crops have been started. Energy efficient greenhouse cultivation continues to be an area of active research and development and this is sought to be achieved through precision equipment and protocols. While the gap between the demand and supply of most horticultural crops remains wide and country plans to double the production of horticultural crops by 2012, the protected cultivation technology holds the key to meet the targets. It clearly emerges that greenhouse technology has multipurpose application for sustainable development of hilly zone. Harsh winter which otherwise threatens the survival of human being in these remote hilly areas, popularization and further improvements in greenhouse management could provide a sign of relief in solitude of white snow cover. Thrust areas for future research are enumerated below :-

- Conservation of more thermal radiation in winter.
- Durable infrastructure modelling.
- Development of successful commercial models
- Modernization of poly greenhouse to permit agro-climatic manipulations of higher magnitude.
- Identification of new crops / varieties suitable for cultivation inside the greenhouse.

- Socio-economic impacts of poly greenhouse technology in Hilly region / cold arid zone.
- Plastic films of suitable grades need to me made available in adequate quantity.
- Development of area specific suitable greenhouse designs
- Standardization of package of practices for growing various crops in greenhouse for specific regions
- Varieties suitable for greenhouse cultivation need to be made available to enhance the productivity
- Vocational training to the unemployed youth and greenhouse practitioners in remote areas to update their skills in this technology.
- Financial assistance as low interest loans should be made available for poor farmers to adopt this technology
- Insurance of greenhouse structure and crop to protect the farmers against the loss caused by natural calamities
- Rigorous extension programme to disseminate the technology information to the poorest of the society.

REFERENCES

- Anonymous(2008).www.wikipedia.org/green house.
- Chandra, P. (1991). The features of solar greenhouse for hill regions of India. Workshop on renewable energy option for Ladakh. SESI, H.P. Chapter, Forestry, Solan, May 3-4, 1991
- Chandra, P. (1996). Protected cultivation for horticulture development. Strategies for horticulture development in India, Dept of Agri. & Co-operation, GOI. 321-8.
- Chandra, P. and Panwar, J.S. (1987). Greenhouse technology and its scope in India. Paper presented in National symposium on use of plastics in Agriculture. Feb.-6, 1987 New Delhi. Proceedings pp 62-66.
- Dwivedi, S.K.; Sareen, S.K. and Paljor Eli (1999). Trench for winter vegetable production in Ladakh (In Hindi) Phal-Phool. 21(4) : 23-24.
- Dwivedi, S.K. and Singh, N. (1999). Roots of green revolution in Ladakh. Indian Farming. 49(I): 20-21.
- Dwivedi S K and Eli Paljor (2010) Green House Technology for higher Himalays.In: Agro Animal Resources of Higher Himalayas. Satish Serial & Publishing House Delhi
- NAEDB, (1992). Action plan on cold deserts: An integrated approach for sustainable development. NAEDB, UHF, Solan - 173230 (H.P.).
- Nimje, P.M. and Shyam, M. (1991). Greenhouse as an alternative technology for commercial vegetable crop production. Indian J. of Agri. Sc. 61(3): 85 -89.
- Sharma, J.L. (1997). Present status and scope of greenhouse in Ladakh. Office of chief Horticulture Officer, Leh.
- Singh, B. (1995 a). Vegetable Production in Ladakh. Field Research Laboratory, C/O 56 APO.
- Singh, B. (1995 b). Greenhouse Development in Leh. Paper presented in Natiional workshop on commercialization of tissue culture and greenhouse technology, Banglore, India 5-6 May 1995.
- Singh, B and Dhaulakhandi, A.B. (1998). Application of Solar greenhouse for vegetable production in cold desert. Renewable Energy : Energy efficiency, Policy and the environment. Proceedings of World Renewable Energy Congress, V, 20-25 September 1998, Florence, Itali 2311-2314.

- Singh, B.; Jadhav, K.L. and Paljor, Eli (1997). In high altitude cold desert of Ladakh. Protected vegetable farming potentials. Indian Horticulture, 42 (3): 16-17.
- Singh, B.; Dwivedi, S.K. and Paljor, Eli. (1998 a). Studies on suitability of various structures for winter vegetable production at subzero temperatures. Paper presented in 25th IHC - Belgium, 2-7 August 1998. Abstract, pp -290.
- Singh, B.; Dwivedi, S.K.; Singh, N. and Paljor, Eli. (1998 b). Sustainable horticultural practices for cold arid areas. Paper presented in Internation symposium on sustainable agriculture in hill areas. 29-31 Oct 1998. H.P.K.V. - Palampur, Absctact pp 35-36.
- Singh B.; Dwivedi, S.K. & Sharma, J.P.(2000). Greenhouse technology and winter vegetable production in cold arid zone. In: Dynamics of cold and agriculture (Eds J P Sharma and AA Mir), pp. 279-93, Kalyani Publishers, New Delhi.
- Sood, Deepak (1987). Greenhouse in India - an overview. Paper presented in National seminar in use of plastice in Agricultrue. Feb.-6, 1987, New Delhi. Proceedings pp 62-66.
- Tewari, G.N. and Dhiman, N.K. (1986). Design and optimization of a winter greenhosue for Leh - Type climate. Energy covers. Mgmt. Vol 26(1) : 71-78.

Table-1: Performance of beetleaf (var. all green) in greenhouse in ladakh during peak winter (Nov. - March)

	Av. plant height (Cm)	Av. yield (kg/m2/cutting)	Total * yield (kg)
Glasshouse	21.8	1.1	3.3
Ladakhi Polyhouse	22.0	1.8	5.4
Polyhouse	19.3	0.9	2.7
Trench	26.8	2.1	6.3
Tunnel	17.0	1.1	3.3
Unit Polyhouse	21.4	1.5	4.5

Table - 2 : Performance of various leafy vegetables grown under polyhouse in ladakh during peak winter (Nov. - March)

Crop/Variety	Av. Plant height (Cm)	Yield /m2 (Kg)
Beet leaf (All Green)	21.36	1.25
Beet leaf (Mongol)	34.44	2.50
Coriander (Local)	39.8	2.25
Fenugreek	39.92	2.50
Lettuce (Great Lake)	23.84	4.50
Veg Mustard (ARU Black)	46.56	4.50

Table - 3: Cost of different greenhouse in ladakh per M2 per year (Rs)

Structure	Total Cost	Life span (Yr)	Area (m2)	Cost(m2/Yr)
Glasshouse	115200	10	40	288.00
Ladakhi Polyhouse	5240	3	50	34.94
Polyhouse	52000	2	70	125.00
Trench	1960	6	24	13.59
Tunnel	6240	2	140	22.29
Unit Polyhouse	5300	2	70	37.86

Table – 4 : Cost of production of beet leaf (Palak) in various greenhouse in ladakh

Structure	Cost (Rs.) (m2 /Year)	Produce (Kg/m2)	Cost @ 15/Kg	Profit (Rs.)
Glasshouse	288	3.3	49.5	-238.5
Ladakhi Polyhouse	35	5.4	81.0	46.0
Polyhouse	125	2.7	40.5	-84.5
Trench	14	6.3	94.5	80.5
Tunnel	22	2.2	33.0	11.0
Unit Polyhouse	38	4.5	67.5	29.5

Table - 5: List of vegetables, their varieties, sowing time and planting distance for winter cultivation in ladakh

Crop	Variety	Sowing Time	Planting distance (cm)
Beetleaf	All green Mongol	First fortnight of Sep.	20
Beetroot (leaf)	Detroit Dark Red	-do-	20
Celery	---	-do-	25
Chenopodium (Bathua)	---	First fortnight of Sep.	10
Coriander	RIL-195	End of Sep.	15
Dums	Local	End of August	20
Fenugreek	Kasuri	Second fortnight of Sep.	15
Karam sag	Khanyari	Second fortnight of August	20
Lettuce	Great Lake	End of Sep.	25
Mint	---	-do-	20
Parsely	Curld leaf	-do-	25
Radish (leaf)	Pusa Himani/Local	-do-	20
Vegetable Mustard	ARU Black	End of Sep.	20

Table 6. Yield of Capsicum and tomato under greenhouse at different locations in India

Location	Capsicum (t/ha)	Tomato (t/ha)
Pune	203.0	124.0
Coimbatore	148.0	186.0
Bangalore	147.0	152.0
Solan	79.0	95.0

Table 7 Comparative performance of solanceous crops in greenhouse

Crop	Fruit yield (kg/m^2)		
	FRP	Trench	Open
Capsicum	1.82	0.83	0.54
Brinjal cv PH-5	1.25	1.09	0.63
Chilli cv. BSS 344	1.35	1.24	0.13
Tomato cv. BSS 347	12.69	-	7.25

Table8 Effect of greenhouse in achieving earliness in some crops

Crop	Days of first picking		Harvesting period (days)	
	FRP	Open	Polycarbonate	Open
Tomato	70	105	100	50
Capsicum	90	127	90	45
Brinjal	92	128	-	-

Table9. Performance of capsicum in various protected structures

Treatments	Days to50% flowering	No. of fruits/plant	Ave. fruit wt (g)	Fruit yield/plant (g)
Greenhouse	63.00	10.4	100.05	937.33
Double Wall Polyench	82.33	7.30	73.33	604.53
L Polycarbonate	71.33	8.50	83.50	719.27
Polyench	74.33	10.4	67.69	642.13
Open	79.00	8.91	42.19	471.93

Table 10 Effect of various structures on capsicum seed production

Treatment	Fruits/ plant	Ave. Fruit wt(g)	Fruit yield/ plant (g)	Seed: Flesh ration	Seeds/ fruits	1000 seed wt(g)	Seed yield plant (g)
Trench	7.27	80.0	550.33	0.27	87.33	5.44	3.56
Polycarbonate	7.93	90.4	634.00	0.22	99.67	5.76	4.39
Polyench	4.50	90.2	384.67	0.19	84.67	5.58	2.12
Open	4.50	63.2	294.00	0.21	52.67	5.42	1.40

Vegetable Grafting for Managing Soil Borne Diseases

Narayan Chawda
VNR Seeds, Village Gomchi (Near nandan Van), P.O. Tendua, Raipur- 492 099 (Chattisgarh)

Growing grafted vegetables was first launched in Japan & Korea in the late 1920s by grafting water melons to gourd root stocks. After the first trial, the cultivated area of grafted vegetables, as well as the kinds of vegetables being grafted, has been consistently increased. At present, most of the watermelons (*Citrullus lanatus*), melons (*Cucumis melo*), green house cucumbers (*Cucumis sativus*), and several solanaceous crops are grafted before being transplanted in the field or in green house. The purpose of grafting also has been greatly expanded, from reducing infection by soil borne diseases caused by pathogens such as *Fusarium oxysporum* to increasing low- temperature and soil and wet-soil tolerance, enhancing water and nutrient uptake, and increasing plant vigour and extending the duration of economic harvest time among other purposes. Growing grafted vegetables, compared to growing grafted trees, was seldom practiced in the United states or in other western countries where land use is not intensive, i.e., proper crop rotation is being practiced. However, it is highly popular in some Asian and European countries where land use is very intensive and the farming area is small.

DAMAGE FROM CONTINUOUS CROPPING: Under continuous cropping were caused by soil-borne diseases and nematodes. Since soil sterilization can never be complete, grafting has become an essential technique for the production of repeated crops of fruit-bearing vegetables.

OBJECTIVES OF VEGETABLE GRAFTING: The main objective of vegetable grafting is to avoid soil-borne diseases such as Fusarium wilt in Cucurbitaceae (Cucumber,melons etc.) and bacterial wilt in Solanaceae (Tomato,pepper etc.).

Grafting's early purpose was to avoid or reduce the soil borne disease caused by *F. Oxysporum*, but the reasons for grafting, as well as the kinds of vegetables grafted, have increased dramatically. Watermelons, other melons (*Cucumis spp.*), cucumbers, tomatoes (*Lycopersicon esculentum Mill.*) and eggplants (*Solanum melongena L.*) are commonly grafted to various rootstocks. Numerous rootstocks also have been developed. Watermelons are commonly grafted to gourds (*Lagenaria siceraria*) or to inter-specific hybrids (*C.maxima x C. Moschata*). Cucumbers are frequently grafted to Figleaf gourd (*C. Ficifolia*) or inter-specific hybrid (*C. Maxima x C. Moschata*)

Eggplants and relatives can be used as rootstocks for tomato. The Asian Vegetable Research and Development Centre (AVRDC) develops *S. melongena* rootstock resistant to water logging as well as bacterial wilt and other soil borne diseases for grafting tomatoes. However, many rootstocks having distinctive characteristics are available today, and growers select the rootstocks, they think are the most suitable for their growing season, cultivation methods, (field or green houses) soil type and the type of crops and cultivars. For example, cucumber grown in green houses during the cool season, should be grafted onto Figleaf gourd; however, those grown

during the hot summer season are usually grafted onto Sintozwa rootstocks (Inter specific hybrid) or others.

Various problems are commonly associated with grafting and cultivating grafted seedlings. Major problems are the labour and techniques required for the grafting operation and post graft handling of grafted seedlings for rapid healing for 7 to 10 days. An expert can graft 1200 seedlings per day (150 seedlings per hour), but the numbers very with the grafting method. Similarly, the post graft handling method depends mostly on the grafting methods. The problems could be minimised or easily overcome by careful cultural management and wise selection of scion and rootstock cultivars.

Since there is prohibition of Methyl bromide for disinfecting soils, there is a renewed interest for grafting eggplant (and tomato) on rootstocks resistant to soil borne pathogens.

Even though there are many problems associated with cultivating grafted vegetable seedlings, the need for successful grafted seedlings is growing rapidly. Breeding multipurpose rootstocks and developing efficient grafting machines and techniques will undoubtedly encourage increased use of grafted seedlings in many countries. Large-scale commercial production of vegetable seedlings is expanding rapidly in many developed countries and this will lead to an increased commercial supply and use of grafted vegetable seedlings throughout the world.

Production of Virus Free Vegetables by using Insect Proof Nets

Continuous cropping of vegetables in a particular area leads to build up of diseases and their vectors. To reduce the problem one of method is to give rest period of 60 days it can be during dry season so that the vector's life cycle is discontinued. This also requires clean cultivation so that all the plant and leaves are killed or removed so that the virus cycle is discontinued. But in many areas this practice is not possible. First farmers don't agree to stop cropping, In many areas dry season is the production time, so other alternative is to grow the crop under nets. Normally 40 mesh net is used which prevents most of the sucking insects to get inside.

Net houses must have double entry sliding gates so that with the movement of farmer the pest doesn't get easy chance to get inside.

Nurseries should also be raised inside net-house to prevent the infection. Use of plastic mulching sheet also reduces the population of sucking pests and thus reduces the chances of viral diseases in the crop.

Use of Electron Microscope for Detection and Diagnosis of Pathogens in Protected Cultivation

Balwinder Singh
Department of Anatomy, G.B.P.U.A.&T., Pantnagar - 263145 (Uttarakhand)

Introduction

One of the most important tasks in the education of a pathologist is learning to distinguish normal from abnormal tissues. Typically, training programs provide an adequate background for the examination and interpretation of tissues at the gross and light microscopic (lm) levels, leaving the student pathologist to his/her own devices to develop necessary skills at the ultrastructural level. The purpose of this presentation is to facilitate development of these skills in ultrastructural examination/interpretation of tissues, by providing a starting point, some tools for study, direction, and finally, a goal at which to aim. Since it would be unrealistic to attempt to go into depth in the short time allotted, the presentation will concentrate on an approach to interpretation of ultrastructural cases while providing a broad overview of some commonly examined tissues.

A human eye can distinguish two points 0.2mm apart. Man's quest to see the unseen and beyond what can be seen with the naked eye led to the discovery of simple magnifying glass that produces an enlarged image of an object. Further improvement led to development of light microscopes that use a combination of magnifying glasses/lenses. Dr.Ernst Ruska at the University of Berlin built the first Electron Microscope (a Transmission Electron Microscope) in 1931 and could get a resolution of 100nm using two magnetic lenses. Today using 5-7 magnetic lenses in the imaging system a resolution of 0.2nm can be achieved. The introduction of the electron microscope as a tool for the biologist brought about a complete reappraisal of the micro-anatomy of biological tissues, organisms and cells. In the early days of its application to biological materials, it was the tool of anatomists and histologists, and many previously unimagined structures in cells were revealed. More recent developments in biological specimen preparation have come from biochemists and physicists who have used the electron microscope to examine cells and tissue in many different ways.

The two most common types of electron microscopes available commercially are the **TRANSMISSION ELECTRON MICROSCOPE (TEM)** and the **SCANNING ELECTRON**

MICROSCOPE (SEM). In the SEM, the specimen is scanned with a focused beam of electrons which produce "secondary" electrons as the beam hits the specimen. These are detected and converted into an image on a television screen, and a three-dimensional image of the surface of the specimen is produced. Specimens in the TEM are examined by passing the electron beam through them, revealing more information of the internal structure of specimens.

The Transmission Electron Microscope (TEM)

The TEM is an evacuated metal cylinder (the column) about 1 to 2 meters high with the source of illumination, a tungsten filament (the cathode), at the top. If the filament is heated and a high voltage (the accelerating voltage) of between 40,000 to 100,000 volts is passed between it and the anode, the filament will emit electrons. These negatively charged electrons are accelerated to an anode (positive charge) placed just below the filament, some of which pass through a tiny hole in the anode, to form an electron beam which passes down the column. The speed at which they are accelerated to the anode depends on the amount of accelerating voltage present.

Electro-magnets, placed at intervals down the column, focus the electrons, mimicking the glass lenses on the light microscope. The double condenser lenses focus the electron beam onto the specimen which is clamped into the removable specimen stage, usually on a specimen grid.

As the electron beam passes through the specimen, some electrons are scattered whilst the remainder are focused by the objective lens either onto a phosphorescent screen or photographic film to form an image. Unfocussed electrons are blocked out by the objective aperture, resulting in an enhancement of the image contrast. The contrast of the image can be increased by reducing the size of this aperture. The remaining lenses on the TEM are the intermediate lens and the projector lens. The intermediate lens is used to control magnification. The projector lens corresponds to the ocular lens of the light microscope and forms a real image on the fluorescent screen at the base of the microscope column.

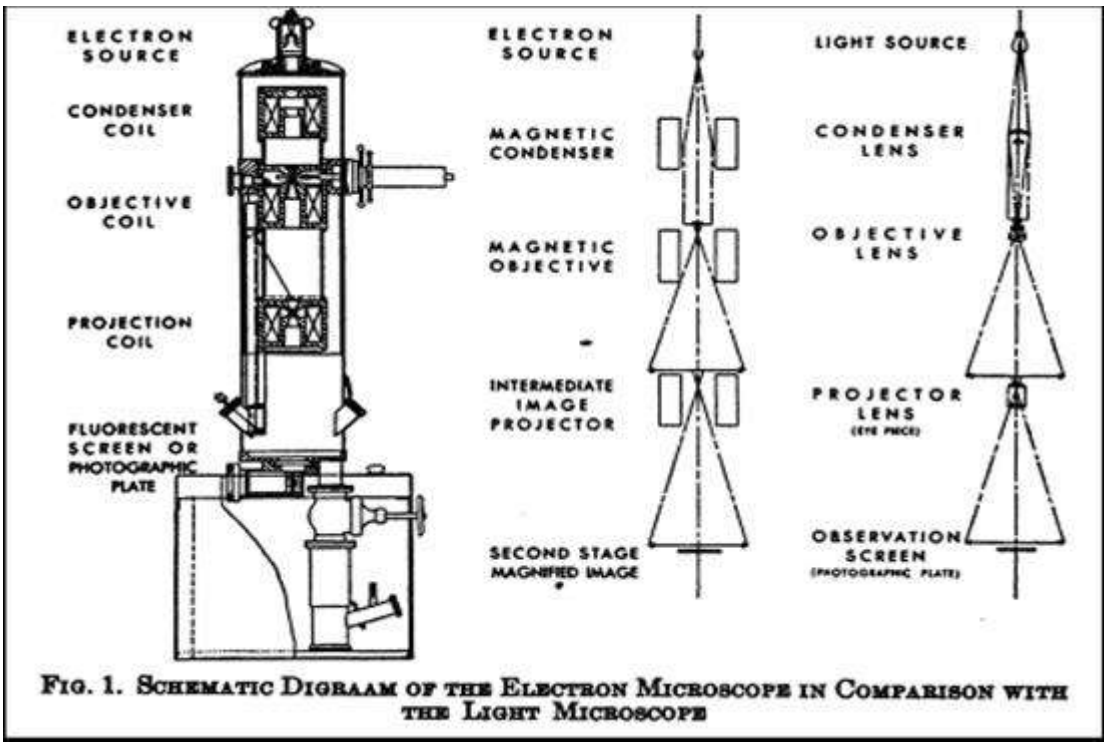


FIG. 1. SCHEMATIC DIGRAAM OF THE ELECTRON MICROSCOPE IN COMPARISON WITH THE LIGHT MICROSCOPE

Resolving Power

The human eye can recognize two objects if they are 0.2mm apart at a normal viewing distance of 25 cm. This ability to optically separate two objects is called resolving power. Any finer detail than this can be resolved by the eye only if the object is enlarged. This enlargement can be achieved by the use of optical instruments such as hand lenses, compound light microscopes and electron microscopes.

Resolution in the light microscope

In the light microscope, the quality of the objective lens plays a major role in determining the resolving power of the apparatus. The ability to make fine structural detail distinct is expressed in terms of numerical aperture (NA). The numerical aperture can be expressed as $n \sin\alpha$ where n is the refractive index for the medium through which the light passes (n air =1.00; n water = 1.33; n oil = 1.4), and α is the angle of one half of the angular aperture of the lens. Light microscope objective and condenser lenses are usually designated by this NA value.

In a light microscope, a beam of light is directed through a thin object and a combination of glass lenses provide an image, which can be viewed by our eyes through an eye piece. The image formed is realistic, because it uses visible multicolor light. Visible light has wave like nature with a wavelength (λ) of 400-800 nm. Since the resolution cannot be less than half the wavelength (λ), the ultimate resolution attainable by using the light microscope is 200nm. This corresponds to a magnification of 1000 times as compared to an eye. Any magnification higher than this will not resolve more detail but will only give “empty magnification”.

(1mm = 1000 µm; 1 µm = 1000nm; 1nm = 10 A^0)

Changes in resolution with wavelength (light microscope)

Light source	Green	Blue	Ultraviolet
Wavelength (nm)	546	436	365
Resolution (nm)	190	160	130

Resolution improves with shorter wavelengths of light

It can be seen from the above table that resolving power improves as the wavelength of the illuminating light decreases. To explain this more fully, the resolving power of the optical system can be expressed as

$$R = \frac{\lambda}{2\,NA}$$

where

- R is the distance between distinguishable points (in nm),
- λ is the wavelength of the illumination source (in nm),
- NA is the numerical aperture of the objective lens.

The optimal resolving power for a light microscope is obtained with ultraviolet illumination (λ = 365) if a system with the optimal NA is used (1.4).

In this example

$$R = \frac{365}{2 \times 1.4}$$

R = 130.4 nm

In the visible region of the spectrum, blue light has the next shortest wavelength, then green and finally red. If white light is used for illumination then the applicable wavelength is that for green. This is in the middle range of the visible spectrum and the region of highest visible sharpness.

Improvement of resolving power

Due to this limitation of resolving power by light microscopy, other sources of illumination, with shorter wavelengths than visible light, have been investigated. Early experiments using X-rays of extremely short wavelength were not pursued further because of the inability to focus these rays. The first breakthrough in the development of the electron microscope came when Louis de Broglie advanced his theory that the electron had a dual nature, with characteristics of a particle or a wave. The demonstration, in 1923 by Busch, that a beam of electrons could be focused by magnetic or electric fields opened the way for the development of the first electron microscope, in 1932, by Knoll and Ruska. Although the initial development of the electron microscope, in Germany, was followed by technical improvements in America, the first commercially available apparatus was marketed by Seimens.

Specimen preparation for TEM

The greatest obstacle to examining biological material with the electron microscope is the unphysiological conditions to which specimens must be exposed.

Since the material must be exposed to a very high vacuum (10^{-5} to 10^{-8} Torr) when being examined, it must be dried at some stage in its preparation. The biological specimen must be stabilized (or fixed) so that its ultrastructure is as close to that in the living material when exposed to the vacuum.

The limited penetrating power of electrons means that the specimens must be very thin or must be sliced into thin sections (50 - 100 nm) to allow electrons to pass through.

Contrast in the TEM depends on the atomic number of the atoms in the specimen; the higher the atomic number, the more electrons are scattered and the greater the contrast. Biological molecules are composed of atoms of very low atomic number (carbon, hydrogen, nitrogen, phosphorus and sulphur). Thin sections of biological material are made visible by selective staining. This is achieved by exposure to salts of heavy metals such as uranium, lead and osmium, which are electron opaque.

Fixatives are used to prevent autolysis, change in volume and shape and preserve various chemical constituents of the cell.

Aims of Fixation

- To preserve the structure of cells and tissues with minimum or least alteration from the living state.
- To protect them against alterations during embedding and sectioning.
- To prepare them for subsequent treatments such as staining and exposure to the electron beam

Commonly used Fixatives

Glutaraldehyde
Paraformaldehyde ⟶ Primary fixative
Acrolein

Karnovsky's Fixative (Glutaraldehyde + Paraformaldehyde)

Osmium tetroxide ⟶ Secondary fixative

Some other compounds are also there which have the ability to partially fix or stain the cellular constituents e.g. Chromium salts, Uranium salts, lead compounds and Phosphotungstic acid (PTA).

Procedure of Fixation and Block Making

Primary fixation

1-2mm sq thick samples + 2.5% glutaraldehyde made in 0.1M sodium phosphate buffer (pH 7.4)	2-24 hours at 4°C

Washing

Rinse thoroughly with 0.1 M sodium phosphate buffer (pH 7.4) to wash away excess fixative

Secondary fixation

Osmium tetroxide (1% solution) is commonly used, acts as electron dense stain reacts principally with lipids.

Washing

Rinse thoroughly with 0.1 M sodium phosphate buffer (pH 7.4) to wash away excess fixative

Dehydration

Ethanol or Dry acetone is used to completely dehydrate the tissue.

Clearing

Xylene, Toluene or epoxy propane is commonly used.

Infiltration

Infiltration is done by gradually decreasing the concentration of clearing agent and proportionately increasing the concentration of embedding medium.

Infiltration is carried out with liquid resins.

Embedding

Embedding is done in the embedding medium using a gelatin or beam capsule

Polymerization

Keep the specimen at 40-50°C for overnight for better penetration of the resin and then increase the temperature to 60°C for 24-48 hrs so that the resin gets hardened.

Removing the Blocks from the mould

After polymerization the blocks can be easily removed.

ULTRAMICROTOMY

Glass knife is used for cutting ultrathin sections. Ultrathin sections show interference colors while floating on the liquid of the trough. This makes it possible to determine the thickness of the sections.

Gray-60 nm (600A0); optimal for high resolution work.

Silver- 60-90 nm; ideal for most of the purposes.

Gold- 90-150 nm; useful for low magnification and autoradiography.

Purple ,blue,green and yellow- range from 150-320nm; very thick sections and not suitable for transmission microscopy.

He sections are picked on to the grids to be observed in the TEM

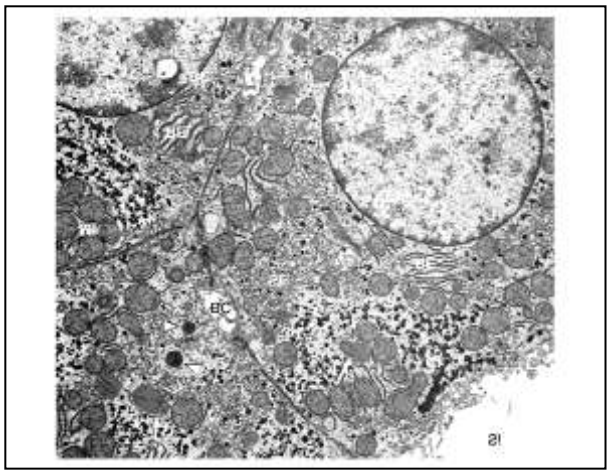
Tem Observations

One of the most important tasks is learning to distinguish normal from abnormal tissues. In order to successfully interpret an electron microscopic (EM) case, you need some of basic tools such as a working knowledge of normal. To describe a micrograph:

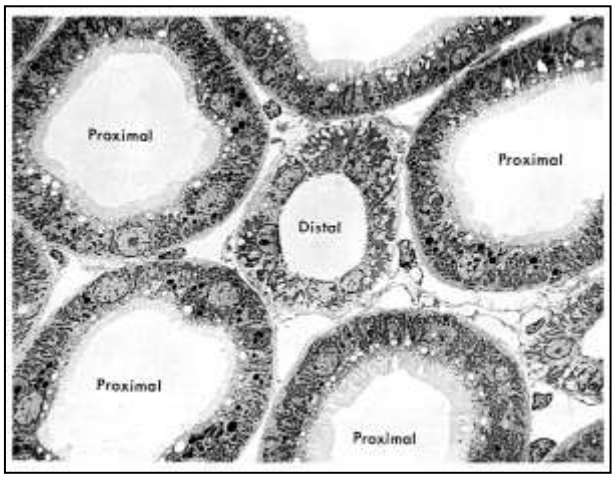
- Begin by stating which tissue(s) is (are) present
- Brief description of normal landmarks present
- Describe pathologic changes
- Have good vocabulary of EM terms - appendix I in the 2nd edition of cell pathology by Cheville has a glossary of EM terms; this is a good starting point.
- *Morphologic diagnosis*
- Same rules apply as for LM cases
- Be concise

Example: hepatocyte: degeneration, diffuse, moderate with intranuclear virions.

Diagnosis must be supported by morphologic description

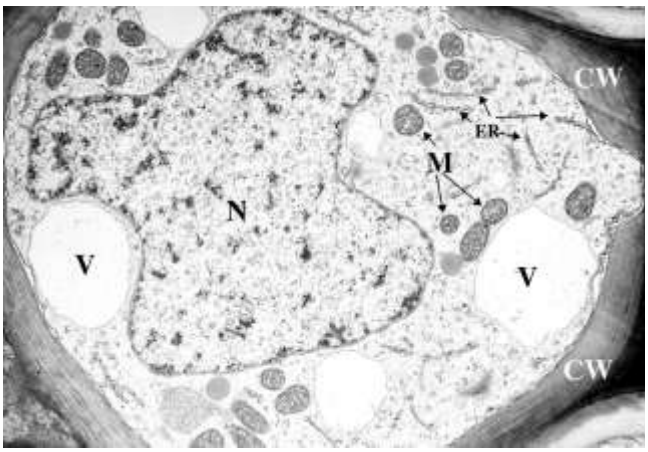


Hepatocyte



PCT Kidney

Below is an EM of a young plant cell: note the nucleus (N) surrounded by a double unit membrane; the cell wall (CW) with its laminated (often amorphous) structure; mitochondria (M) with their internal cristae, the vacuoles surrounded by a single membrane (tonoplast), and the endoplasmic reticulum (ER). The dots throughout are ribosomes.



Nucleus: identified by its size, double unit membrane, and granular texture (due to chromatin).

Cell Wall: identified by its laminated or amorphous texture.

Mitochondria: identified by their size, by their double unit membrane, and by the enfoldings of the inner membrane called cristae.

Plastids: Identified by their double unit membrane.

Leucoplasts can be identified by their absence of cristae or chromatin.Leucoplasts may have amorphous starch grains, or crystalline protein.

Chloroplasts can be identified by their stacks of thallakoid membranes called grana.

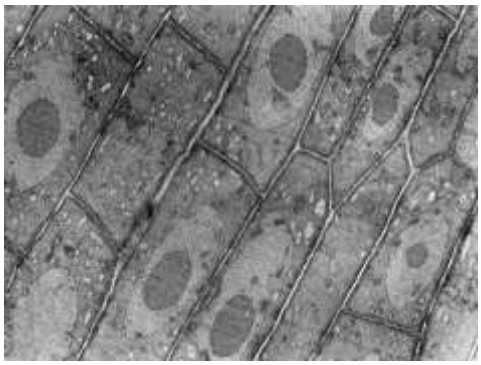
Vacuole - Vacuole membrane: Vacuoles are surrounded by a single unit membrane. The texture inside is clear - evidence of the absence of other cellular components.

Microbodies: Have a single unit membrane and are usually dense in appearance.

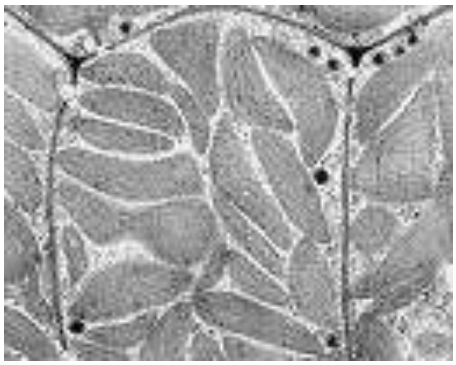
Golgi Bodies: In cross section appear as a stack of membrane-bound compartments resembling a cross section of a stack of pancakes.

Endoplasmic Reticulum: Membranes that pervade the cell, seemingly not associated with any of the structures listed above. If ribosomes are clustered along these membranes is called rough ER.

Ribosomes: dot-like structures often associated with endoplasmic reticulum.

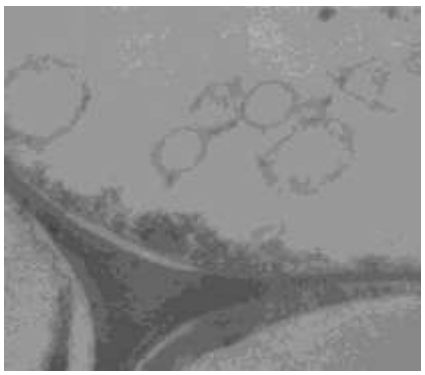


Meristematic cells in roots parenchyma from Glycine hispida (10000X)



Chloroplast in Leaf Material

Thicker ascospore walls (TEM) fungus



TEM of phytoplasma colonizing the phloem of an infected stem.

Infectious Agent

A complete treatise of ultrastructural detail of infectious agents is beyond the scope of this presentation. Generally speaking, it is easy to get carried away describing these organisms in any detail, especially protozoa. It is better to describe the essentials, interpret and continue.

Viral

In describing viruses, describe size if a scale marker is present, shape, encapsulated or not, appearance of nucleoid, and where virus is present (intranuclear, budding from cell membranes/ walls, within er, extracellular, etc.).Some viruses are more easily identified ultrastructurally than others:

Poxviruses- relatively large viruses (200-300 nm), replication in the cytosol unlike most DNA viruses, substantial capsule and dumbbell-shaped nucleoid.

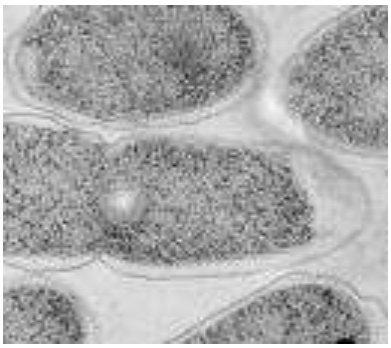
Adenoviruses- characteristic intranuclear paracrystalline array.

Herpesviruses- replication in nucleus where immature nucleocapsids are present, envelope by budding through a membrane (often nuclear, sometimes er or plasma membrane).

Bacterial

Be familiar with general ultrastructural morphology of a bacterium. Knowing the species of plant / animal, the tissue involved, and occasionally some other features, you can make an

educated guess as to the bacteria with which you are dealing. Describe size if a scale is given, shape (coccus, rod, pleomorphic) and where bacteria are located (i.e. At microvillar tips, closely-adhered to cell membrane / wall, intracytoplasmic and if so, within phagolysosome or free).

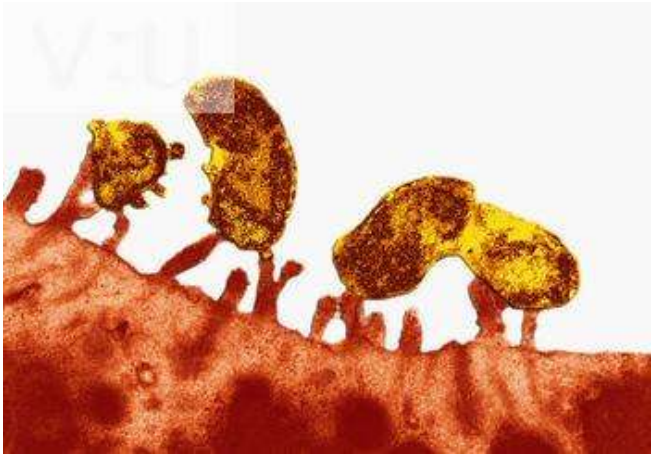


Pseudomonas putida under solute stress

Pseudomonas putida with no stress

Examples:

Bordetella- bacteria enmeshed in tracheal cilia; animal affected may be dog, turkey, etc.Car bacillus- bacteria enmeshed in cilia of airway, but more likely in a rat.



These Helicobacter pylori Bacteria (formerly named Campylobacter) on human stomach epithelial cells can cause certain types of stomach ulcers and gastritis. Peptic ulcers are holes or sores in the stomach or duodenum and most are caused by this pathogen. With antibiotics, the infection can be cured in a few weeks. TEM X40,000

Protozoal

Be familiar with some of the terminology used in describing protozoa, such as conoid, micronemes and rhoptries. Note whether zoites are contained within a parasitophorous vacuole or free in the cytoplasm. If in a bradycyst, is wall thick or thin? Some familiar examples include:

Giardia- elongated, attached along microvillar surface

Cryptosporidium- trophozoites attached to apical cell surface by feeder organelle, microvilli are effaced only at the site of attachment. The trophozoites develop into schizonts.

Journals relating to Electron Microscopy

- Journal of Electron Microscopy (Japanese)
- Journal of Electron Microscopy Techniques

- Journal of Microscopy
- Biology of Cell (French)
- Journal of Ultra-structural Pathology
- Scanning Electron Microscopy
- Ultramicroscopy
- Developmental Dynamics
- Anatomical Record
- Journal of Cell Biology
- Tissue and Cell
- Electron Microscopy Reviews
- Journal of Ultra structure and Molecular Structure Research
- Cell and Tissue Research

Evaluation of Risks Related to the Release of Biocontrol agents Active against Plant Pathogens

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

Biological control has been actively practiced for more than 100 years and the history of biocontrol, its failures and successes, has been extensively reviewed by many researchers in different parts of the world. Biological control is the deliberate use of one or more organisms to suppress the growth or reduce the population of another organism to a level at which it is no longer an economic problem. Two basic biological control methods include “classical” biological control (CBC) and the “inundative” strategy. The classical strategy is also termed the “inoculative” method, as it usually involves a small “dose” of an exotic biological control organism, applied once or only occasionally, to a host population of weeds that is usually of foreign origin. The “inundative” method involves single or multiple applications of a biological control agent to a pest at much higher concentrations than ordinarily encountered. The term mycoherbicide usually refers to an indigenous fungus applied in an inundative manner to control native weeds. The inundative method involves application of sufficiently high levels of inoculum to the weed population, under conditions that favour disease onset, to quickly create a disease epidemic among plants. The organism that suppresses the pest or pathogen is known as Biological control agent (BCA). The biocontrol agents provide protection against plant diseases either by direct action against the pathogen (i.e. antagonism) and/or indirectly by reducing host susceptibility towards the pathogen. As an antagonist, biocontrol agent may directly kill the pathogen by mycoparasitism and/or antibiosis. It may adversely affect the growth and development of the pathogen either by antibiosis or by competing for the nutrient, oxygen or space. Antagonist like *Trichoderma* is not only capable of colonizing and killing the hyphae but also hard sclerotia of the fungal plant pathogens. Many antibiotics have been isolated and characterized from fungal as well as bacterial biocontrol agents. Soil pseudomonads generally produce fluorescent, yellow green, water-soluble siderophores with both a hydroxamate and phenolate group. Biocontrol agents are microorganisms that adversely affect the population of another microorganism (e.g. target pathogen) growing in association with them. Generally biocontrol agents have potential to interfere in the life process of plant pathogens both directly as well as indirectly. Biocontrol agents include virtually all classes of organisms’ e.g. fungi, bacteria, nematodes, protozoa, viruses and seed plants.

Advantages and benefits of Biological control- various advantages of biocontrol are as follows.

- Reduce the use of chemical-based fungicides.
- Reduce the risk of developing pathogen resistant to traditional chemicals.
- Safer to use.
- More stable than chemical pesticides if stored properly.
- Lower re-entry interval (R.E.I.) times.

- Less phytotoxic.

Benefits - factors such as increase in yield of the crop that is normally impacted by the weed. It also include secondary features such as reduction in the usage of chemical herbicides, which account for 85% of pesticide use in the United States (Templeton 1992).

Fungal and bacterial biocontrol agents are part of natural ecosystem. They are present in the rhizosphere and can be isolated from any type of soil. All microorganisms produce metabolites- either beneficial or harmful. Fungal BCAs are specialized and often confused with fungi producing mycotoxins (*Aspergillus, Fusarium* etc).

Consumers concern regarding mycotoxins entering the food chain has prompted closer scrutiny of all the secondary metabolites produced by different biocontrol agents. Biocontrol agents produce some metabolites in the form of siderophores, enzymes or toxins, to displace/inhibit competitor. This enables the BCA to compete for nutrients and space. Also for its survival, metabolites protect BCA against antagonistic microorganisms or mycophagous organisms.

Limitations of Biological control- Biological control is not a panacea and is not risk-free (Delfosse, 2000). In certain disease management needs and situations where, clearly, another strategy is more appropriate or should have higher priority. For example, if a new, potentially invasive pest is found in a localized area, the appropriate strategy is eradication with pesticides. Biological control is a strategic process with limited use in emergency pest control programs. Every biological control agent that has ever been used has associated risk. The quantification of that risk is a very challenging and difficult activity, which has been the subject of extensive research and discussion.

Risk and biological control- Risk is the probability of the occurrence of a hazard or potentially harmful effect. It is a relative concept used to imply uncertainty, and estimates and perceptions of risk change as knowledge improves. Risk can be expressed as the interaction between hazard and exposure. For risk, the perception is often higher than the reality. Risk is often used when uncertainty can be quantified to some degree.

An *uncertain risk* suggests a paradox and a contradiction in cases where the existence of a hazard has not been established, often a case in Biological control.

Acceptable risk - when uncertainty is quantified to the subjective satisfaction of a viewer.

An *irreversible action* - limits future options.

Option value arises from retaining an option to a good or service (including, for example, both the target species and potential nontarget species) for which future demand is uncertain.

Risk analysis- body of knowledge (methodology) that evaluates and derives a probability of an adverse effect of an agent (chemical, physical, or other), industrial process, technology, or natural process.

Risk analysis is comprised of risk assessment, risk management and risk communication. In risk analysis, probabilities of possible outcomes are estimated. Risk analysis should be a

transparent public process, with all assumptions and parameters clearly stated. For biological control, the adverse effect is damage (anticipated or not) to a nontarget species from a bioagent. Understanding the nature of this damage is the key, and there is a continuum of type, extent, temporal, and spatial aspects of damage that must be considered.

Common elements in risk analysis:

- **Hazard (agent) identification-** Hazard as the innate capacity of a biological control agent to cause harm to non targets.
- **Dose-response**- The relationship between the population level and incidence of a biological control agent and the adverse effect.
- **Exposure analysis-** What current or future exposures are anticipated in all habitats where the host or potential nontarget species occur? What phenological, temporal, spatial, edaphic, climatological, or other features may mediate exposure?
- **Risk characterization-**Given the information from the first three points in the risk analysis process, what is the estimated incidence of the adverse effect in a given population? What other information is needed? Does the physiological host range determined by host-specificity testing predict accurately the ecological host range?
- **Risk assessment-** Risk assessment is risk analysis applied in a particular situation. Acc. to U.S. Environmental Protection Agency (EPA) (1992) ecological risk assessment is "the process that evaluates the likelihood that adverse ecological effects are occurring, or may occur, as a result of exposure to one or more stresses." For biological control, risk assessment examines adverse effects of a biological control agent on nontarget species, but can be expanded to include other aspects of the environment.
- **Risk management**- Risk management identifies and implements strategies to reduce risk to an acceptable level.

Risk communication- the objective communication of risk to the general public is the least-developed part of the risk analysis process for biological control. Biological control scientists communicate the risks of biological control to colleagues through publications, scientific and public meetings, etc., and to regulatory officials through permits for importation and release of agents, but not very well in general to the public. The nature of risk from biological control: Release of a classical biological control agent is *irreversible action;* if the agent becomes established, it is unlikely to be able to be recalled. A biological control agent could limit the option value of the target species and of any nontarget species that are in its ecological host range. Thus, assessment of the potential risk from biological control is not simple, and over simplification can lead to erroneous conclusions. The crucial variable of risk (and most fears) in biological control is measured by assumption of potential damage to valued nontarget species.

Risks of biocontrol agents:

	Effects inherent to the pathogen	Effects due to other factors
Direct effects	Pathogenicity	Undesirable microbial contaminants during the production
	Toxicity/mutagenicity	
	Irritation	
	Allergenicity	Carriers, additives and adjuvants
Indirect effects	Competitive displacement of other organisms	
	Genetic instability of the fungal biocontrol agent	

Other factors limiting successful biocontrol are persistence and survival of bioagents , susceptibility to environmental changes and pathogens self defense. Since microorganisms are capable to grow and multiply in many environmental conditions, clearance of microorganism has to be studied, making the studies more difficult and costly.

Toxicity studies for the microorganism / metabolite: the toxicity tests to be conducted should take into account the main route of exposure. There are following toxicity parameters required for release and registration of biocontrol agents.

- Acute oral toxicity- acute oral toxicity refers to those adverse effects occurring following oral administration of a single dose of a substance, or multiple doses given within 24 hours.
- Acute inhalation toxicity-Acute inhalation toxicity is the adverse effect caused by a substance following a single uninterrupted exposure by inhalation over a short period of time (24 hours or less) to a substance capable of being inhaled.
- Genotoxicity- Genotoxicity describes a deleterious action on a cell's genetic material affecting its integrity. Genotoxic substances are known to be potentially mutagenic or carcinogenic, specifically those capable of causing genetic mutation and of contributing to the development of tumors. Similar to sensitization, genotoxicity testing poses methodological problems.

Considering that inhalation is the most appropriate route of contamination, intratracheal acute toxicity seems appropriate. But to test toxicity, animal (mammal) testing is costly, required suitable facilities and equipment and specialized personnel and has ethical issues. Now researchers have focused on the development of alternative methods for toxicity assessment. Quantitative structure-activity relationships (QSARs), Lower organisms (bacteria, fungi, plants), Invertebrate animals, Vertebrates at early stage of development, *In vitro* systems (cell and tissue cultures) are some newly developed methods. Recently, invertebrates like *Artemia salina* and *Daphnia magna* were used for toxicity and allergenicity analysis. *Artemia salina* is a sea water organism, used for eco-toxicity testing (acute toxicity) for estuarine/marine environments and *Daphnia magna is a f*reshwater organism, used for eco-toxicity testing (Acute and chronic, sub-lethal, toxicity) for terrestrial and freshwater environments, Accepted by international standard organizations (ISO, OECD, and ASTM). Both of them were accepted by EU (67/548/EEC, 91/271/CEE, 91/676/CEE) and EPA for eco-toxicological assessment.

Non target effect of BCAs- Non-target effects of bacterial biological control agents on soil protozoa has been found recently. Negative effects of *P. fluorescens* DR54 were assessed on growth of the amoebae *Hartmanella vermiformis* and *Acanthamoeba* sp. cultures and natural assemblages of soil protozoans. The observed effects were larger than those of the *P. fluorescens* type strain DSM50090 and *Enterobacter aerogenes* SC and were tentatively attributed to viscosinamide, which is an antimicrobial compound with surfactant properties produced by *P. fluorescens* DR54.

Possibility of Gene transfer in Biocontrol Agents: Transfer of agrocin plasmid p AgK84 to pathogenic *Agrobacteria.* Pathogenic strains acquired resistance to Agrocin 84 and also produce it. Mobilization of plasmid deleted by producing Tra^- (transfer deleted) mutant of K84. *A. radiobacter* K1026

Pathogen self defense: is mechanism to counter act Biocontrol Agents. Pathogen populations are not evolutionary static entities. Pathogens have diverse responses to counteract antagonism which can affect the efficacy of biocontrol.

- Pathogen defense against antibiosis -Natural diversity in sensitivity of pathogens to antibiotics : *Pseudomonas* strains fail to control take-all caused by 2,4,-DAPG insensitive *G. graminis* var. *tritici*. Resistance to Antibiotics : *Agrobacterium tumefaciens* – Agrocin 84 .
- Pathogen defense against competition - Altering the environment : *A. tumefaciens* programms host plant to produce opines, that can not be utilized by other competitors. Shutting out competitors: *Pseudomonas syringae* – phytotoxins – stomatal closing.
- Pathogen defense against mycoparasitism- Reverse Mycoparasitism : Pathogenic *F. oxysporum* have the ability to parasitize *T. hamatum*, *T. harzianum*, *T. longibrachiatum* and *T. pseudokoningii*
- Bacteriophage resistance : *Erwinia amylovora* – variations in sensitivity to bacteriophage.

Persistence and survival of biocontrol agents:

- Inadequate establishment and survival of biocontrol agents under field conditions.
- Microbial climax community resist invasion by introduced exogenous organism. Short time persistence.
- Continued applications are necessary.
- Environmental factors influencing persistence of metabolites (toxins) produced by BCAs:
    - Biotic – metabolites destroyed or exploited by plant/soil microbes
    - Edaphic– metabolites adsorbed onto soil particles/inactivated due to soil chemistry (e.g. pH)
    - Climatic – metabolites inactivated by UV or heat, diluted by rain

Key elements for risk assessment of BCAs: The identity of the isolates- in particular their relationships with human pathogens;

- The biological properties of the isolates- in particular their mode of action, the biotic and abiotic factors determining the potential for persistence in the environment and for reproduction, growth, or persistence in vertebrates;
- The quality assurance of the production process, specifically the control of the presence of

microbial contaminants;

- The presence of toxins or secondary metabolites (e.g. destruxins).
- Development of genetic markers for risk assessment of BCAs: Analysis of the genetic structure of a species can reveal information about its population structure and permit risk analysis. Recently, genetic markers have been developed and are being used to analyze gene flow between populations. Assessment of genetic variation is done by using Ribosomal DNA (rDNA), mitochondrial DNA, and RAPDs. Analysis of the distribution of markers in a fungal bioagent, *Chondrostereum purpureum* indicated that there were indeed no barriers to gene flow and that the introduction of rare pathogenicity alleles from isolates used as biological control agents would occur at a low probability.
- **Tools to monitor metabolites and fungal BCAs in the environment**: Species-specific probes:

Trichoderma specific primers based on conserved regions for the species, within the IGS region of rDNA, which were variable for a range of other soil filamentous fungi has been developed and used for assaying gene flow. With the development of high throughput assays like ELISA and Vito ox it becomes easy to determine cytotoxicity and genotoxicity. These assays help in the detection/quantification of metabolites.

Recommendations for risk assessment of BCAs

- Risk assessment for biological control agents should follow the standard protocol for ecological risk assessment with appropriate modifications.
- Potential uses of demographic elasticity analysis in risk assessment for proposed weed biological control agents should be thoroughly explored.
- Following the problem formulation phase of the risk analysis, hazard identification and effects analysis should be performed. If the proposed agent poses a significant hazard to non-target species, the assessment should proceed with an exposure analysis. Individual-based models should be given serious consideration for any exposure analysis that proves necessary. The data required to estimate the movement parameters of such a model are relatively easy to collect. Risk assessments should be explicitly linked with cost-benefit analyses in a unified decision-theory framework.

Fate of BCAs in the environment- Study on fate and behaviour of plant protection products in the environment poses quite different questions, depending on whether the product is a chemical or a microorganism. Biocontrol product is based either on a naturally occurring biological molecule or a living microorganism. There is an unjustified fear that an introduced microorganism will become a pest after establishment.

In relation to biocontrol agents, till now there is no clear example of an introduced microorganism, becoming dominant. However since it is not possible to rule out any associated risk, it is necessary to study the fate and behaviour of bioagent in the environment.

Production and Management of Chrysanthemum under Greenhouse

Ajit Kapoor
Department of Horticulture, G.B.P.U.A&T., Pantnagar- 263 145 (UK)

India-Flower Power on its Way

- The Netherlands and Japan are taking India as serious player in the field of floriculture.
- Foreign players are showing increasing interest in investment and technology upgradation.
- Domestic consumption is increasing at a whopping rate of 40% per annum.
- Major flower growing regions are Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu and West Bengal.
- New potential regions are North East India, Sikkim, Arunchal Pradesh, Himachal Pradesh and Uttarakhand.

What India does Offer

- Varied agroclimatic conditions
- Abundant sunlight and water
- Availability of skilled and semi-skilled labour
- Proximity to West Asia, South East Asia, Far East and Europe.
- Insight into international markets gained in the last two decades.
- A large and rapidly growing domestic market.
- Government support for export oriented production.
- Cost-effective technologies for protected cultivation
- Upcoming handling facilities at major airports.

What India can Offer

- Diversified products
- Cut flowers: Rose, lilium, tulips, carnation, gladiolus and gerbera.
- Novelty flowers: Anthurium, orchids, bird of paradise and heliconia.
- Pottted plants, ornamentals and foliage.
- Quality planting material like seeds and bulbs.
- Value added products like dried flowers, flower arrangements, essential oils, pellets natural pigments and colours.

New Developments in the field of Indian Floriculture

- Concentrated pockets coming up with common infrastructure and logistics like
- Tankflora Park in Tamil Nadu.
- Talegaon Floriculture village in Maharastra
- Flower auction markets coming up in major cities like Mumbai, Bangalore and Noida.
- Perishable handling facilities at Delhi, Bangalore, Mumbai, Hydrabad and Thiruvananthapuram.
- Market facilitation centre at Aalsmeer.

Major Constraints

- Lack of air cargo space and high cost of freight.
- High cost of imported planting material.
- Lack of post-harvest infrastructure facilities and proper logistic support.
- Inadequate infrastructure facilities at the export gateways.
- Inadequate funding from financial institutions due to lack of knowledge and perceived risks.
- Market intelligence not available on regular basis.
- Industry fragmented and not vertically organized.

Chrysanthemum (*Dendranthema grandiflora*) is an important flower crop next to rose in importance in the international florists trade. Third position in India after jasmine and rose. It is also known as "Queen of East". It occupies a place of pride of a commercial flower crop and popular exhibition flower. There is wide variation exhibited by large number of cultivars. In Chrysanthemum *Chrysos* means golden and *anthos* means flower. The basic number of the genus is 9 and wide range of ploidy level is found with 2n=36, 45, 47, and 51-57.

Importance and Uses: Chrysanthemum is among the most interesting group of ornamental plants in the world and represents perhaps the oldest ornamental flower. It is also the leading commercial flower, important both as cut flower and as potted plant in the international market. Tall and erect varieties are suitable for background planting in borders. The compact & dwarf varieties are used for pot culture. Flower with attractive colors with long stem having long vase life are suitable for cut flower production. Decorative small flowered varieties are useful for loose flower and garland making and hair adornment. The varieties having large flowers are used for exhibition purposes. It is preferred particularly due to the range of shapes and sizes of flowers, brilliance of colours, long lasting flower life, diversity in height and growth habit of the plant, exceptionally hardy nature, relative ease to grow all the year round and versatility of uses. *Chrysanthemum cinerariefolium* & *C. coccineum* are cultivated as source of 'pyrethrum' (an important insecticide).

Origin and History: Native to Northern hemisphere (Europe & Asia). First written mention seems to be in Gyaneswari (1290 AD chapter 15, Shloka 20) by Sant Gyaneswar. This flower was highly respected by Chinese and export was not allowed to other countries. However, the seeds of chrysanthemum reached Japan from China via Korea as early as 386 AD. After reaching Japan, chrysanthemum underwent miraculous transformation and today Japan has the highest number of chrysanthemum cultivars in the world. Hindi name *guldaudi* meaning 'flower of *Daud*' suggested that it must have been grown during the mughal period in this country.

Soil: Well drained, sandy loam with a pH of 6.5-7.0. The EC should be 1.0-1.5 with low levels of NaCl and sulphates. This is shallow rooted crop and very sensitive to waterlogged condition. Very light sandy soils are not recommended owing to their poor water holding properties.

Climate: It can be successfully grown up to an altitude of 1200 m MSL. It is a short day plant. Chrysanthemums require long days for good vegetative growth and short days for flowering.

Based on temperature requirements, chrysanthemum cultivars are classified into 3 groups:

A. Thermo zero cultivars: They flower at any temperature 10-27ºC; consistency is at 16 ºC.
B. Thermo positive cultivars: They require a minimum of 16ºC for bud initiation and at 27ºC there will be rapid initiation.
C. Thermo negative cultivars: Bud initiation occurs at low or high temperature between 10ºC and 27ºC but continuous high temperature delay bud development.

Propagation

1. Terminal cutting: This is commercial method. In this method, 5-7 cm length cutting are made by shearing basal leaves and cutting half of the open leaves. Cuttings are dipped in 2500 ppm IBA or eradex/keradex. Cuttings are put in the plug trays or sand bed in semi shed condition and watered immediately and thereafter regularly. Use of mist chamber for rooting of cutting result in higher percentage of rooting. Terminal cuttings are taken in June and transplanted after rooting at the end of July.

2. Suckers: After flowering, the stem is cut back just above the ground to induce the formation of suckers. Suckers are separated from the mother plant carefully. Plant in the sand bed or can be directly transplanted in field.

Disadvantages: a. Transmission of parental diseases
b. Lack of uniformity
c. Poor flower quality
d. Less number of plants produced

3. Micropropagation: Multiply at a fast rate by culturing shoot spex *in vitro* from somatic callus, peduncle leaves and other floral parts. Here 2-3 cm long terminal cutting with at least one node are taken, washed and further trimmed after sterlizing in 70% ethanol followed 4% sodium hypochloride, place them on nutrient agar substrate in test tubes kept in 23.2^0C for 16 hr/day under 4000 lux. Rooted mini cuttings are potted in peat and kept at $20\text{-}25^0$C for 10-15 days before planting out.

Cultivars: The choice of cultivars varies with purpose of the plant to be grown. This varies with the uses as given below:

Pot mum: Dwarf and compactness, profuse branching, uniform spreading of branching, simultaneous blooming habit, attractive color and good colour retention, quality and health of leaves.

Cut flower purpose: Attractive colour, long erect stem, uniform bloom opening, tough florets, long vase life and healthy leaves.

Garland type: Yellow or white colour of blooms, diameter of bloom about 5 cm. Fluffy blooms, disc absent or invisible, good quality recovery from pressure, high yielding (15 tons/ha or 150 g/plant). Good colour retention. Long blooming season. Profuse branching and sweet scented blooms.

A. Large Flowered (Exhibits):

White colour: Snow Ball, Kasturba Gandhi, Beauty and Innocence

Yellow colour: Chandrama, Sonar Bangla, Super Giant and Evening Star.

Mauve colour: Mahatma Gandhi, Peacock, Raja and Pink Giant.

Red colour: Diamond Jubilee, Alfred Wilson and Distinction.

B. Small- Flowered (Cut flowers):

White colour: Birbal Sahni, Apsara, Himani and Baggi

Yellow colour: Nanako, Jayanti and Kundan.

Mauve colour: Sharad Prabha, Nilima and Ajay.

Red colour: Jaya, Flirt and Jubilee.

C. Small- Flowered (Pot culture):

White colour: Sharad Shoba, Shweta Singar, Jyotsana and Niharika

Yellow colour: Indira, Archana, Sonali Tara and Sharad Kanti.

Mauve colour: Sharad Prabha, Mohini, Hemant Sagar and Fantasy.

Red colour: Rakhee, Gem, Jaya, Flirt, Arun Singar and Suhag Singar.

Time of planting: Terminal cuttings of stock plants are taken in June and they are transplanted after rooting in 15 cm pots at the end of July. These plants are ready for pinching during end of August or beginning of September.

Spacing: 30 x 30 cm (plant to plant and row to row)

Nutrient Management: As the crop responds well to manuring, add 20-30 tonnes of well rotten FYM per hectare. Apply 125 kg of Nitrogen, 400 kg P_2O_5 and 200 kg K_2O per hectare is recommended.

Irrigation/Water Management: The frequency of irrigation depends on the stage of growth, soil and weather conditions. Proper drainage system should be maintained for chrysanthemum grown both in beds and in pots. The height and vigour of the chrysanthemum plant can be influenced by regulating quantity and frequency of irrigation.

Weed Management: Weeds should be avoided in the greenhouse as well as fields. Frequent shallow cultivation should be done to conserve moisture and control weeds. In greenhouse grown chrysanthemums, weeds can be controlled with Tenoran (Chloroxeron) @ 300g + Dachthal (Chlorathal di-methyl) 900 g/1000 m^2 applied 1-2 days before planting of the rooted cuttings.

Important horticultural practices

1. Pinching: Soft vegetative shoot tips of 1.5-3.0 cm long size are removed to encourage the side branches with more number of blooms.

Soft Pinching: It is most commonly practiced because bud remaining on the stem break rapidly, it involves removal of tip of shoot along with 2-3 open leaves.

Hard Pinching: It is used to reduce plant size specially in pots, but bud do not break as rapidly as soft pinch.

Roll out Pinching: It is used only on short plant or soon after cutting are planted.

2. Disbudding: It is done to remove the side branches, which arise from axillary buds. Number of flower is limited and bloom of better size is obtained. In standard chrysanthemums, regular disbudding is done to obtain a single large bloom.

3. Staking: Staking is necessary to provide the support & maintain proper shape of plants & blooms. There are only a few varieties which neither require pinching nor staking and hence known as 'no stake no pinch' varieties. In standard type, number of stakes is dependent on the number of main branches and in spray type, 3-4 stakes are inserted.

Growth regulation: Growth regulation can be done by controlling the environment as well as by use of plant growth regulators. Long day conditions result in extended vegetative growth and induction of short days result in flower bud initiation.

GA_3 50 ppm spray at 30, 45 and 60^{th} day after planting increases the total flower yield. Number of quality flowers can be increased by spraying triacontanol (100 mg/l). Ascorbic acid spray at 1,000 ppm either on 35^{th} day or 70^{th} day after transplanting significantly increased the overall growth rate. B-nine (5,000 ppm) spray resulted in highest number of flowers per plant.

Plant Protection

Diseases

1) Root rot (*Pythium* spp or *Phytophthora* spp.): In this disease, the infected plant suddenly wilt the plant parts like roots, stems, leaves.

Control measures

i) Provide good drainage conditions to prevent water logging.
ii) Soil drench with thiram or captan or mixture of both at the rate of 2.5 g/m^2 area prevents the infection.
iii) Mancozeb, Metalaxyl and Fosetyl- also used for control.

2) Leaf spot (*Septoria chrysanthemella*): Greyish brown spots appear on leaves which turn yellow surroundings. When flowering starts, the infection occurs on flower buds, which rot completely. The disease spreads from down to upwards.

Control measures

i) Spraying with mancozeb at fortnightly interval helps in controlling the disease.
ii) Burning and destroying of infected leaves.
iii) Spray of Copper oxychloride (0.2%).

3) Wilt (*Verticillium dahliae*): The leaves turn yellow to grey and the branch or whole plant wilts gradually. It may occur due to a number of diseases, disorders or even just lack of water.

Control measures

i) Solarization of soil by using black polythene mulch during summer months.
ii) Soil treatment with Dithane M-45 (0.2%)
iii) Dipping of rooted cuttings in Benomyl suspension before planting.

iv) Use of resistant varieties.

4) Rust (*Puccinia* spp): It is serious disease especially in the early spring. Brown spores appear in the underside of the leaves. Severely infected plants become very weak and fail to bloom properly.

Control measures

i) Sanitation and clean cultivation prevent the disease.
ii) Early removal of infected leaves.
iii) Dusting plants either with sulphur and other fungicides such as Zineb, Captan, etc. can be used.

5) Powdery mildew (*Oidium chrysanthemi*): There is powdery coating on the leaves appear. It may lead to defoliation.

Control measures: Use of Sulphur fungicides or Carbendazim.

Viral disease

Chrysanthemum stunt: - Overall reduction in plant size, foliage become pale in colour, flower may open prematurely. Disease occur diving pinching. This disease occurs during pinching.

Control measures: Use of cuttings from virus free plants.

Pests

1) Aphids (*Myzus perricae*):This are small greenish-to-black dot like insects which are seen in large number sucking the sap from the tender parts like stem tips, flower buds and young leaves. The affected flower buds fail to open and dry up before opening. Damage begins in December and is in peak during Feb-March.

Control measures: Spraying at fortnightly interval with 0. 5% Monocrotophos, or 0.1% Malathion or 0.02% Phosphomidon.

2) Mites (*Tetranychus urticae*): Very minute dot-like insects of red colour seen on the under surface of leaves, particularly in hot dry season. The affected flower buds fail to open and dry up even before opening.

Control measures: Spray of 0.05% Dicofol or 0.05% Vertimac or Pentac at fortnightly interval.

3) Thrips (*Thrips tabaci*): - Thrips cause damage to summer blooming varieties. Infected flowers discoloured & dry.

Control measures: Spraying Dimethoate at 0.05 per cent 2 or 3 times at 15 days interval.

4) Leaf miners (*Phythomgza syngenesiae*): Incidence is maximum during March-June. The infestation is more severe in polyhouse. The young maggot stage attacks the leaves by making tunnels in between the upper and lower surface of the leaf. In severe cases, the leaves completely dry up and fall off.

Control measures:

i) Removal & destruction of affected leaves help in containing the spread.
ii) Spraying of 0.05% Monocrotophos or 0.05% Triazophos.

5) Leaf folder: -All the larval stage attack the plant with the help of silky threads, the larve folds the leaves & starts feeding on leaves from inside.

Control measures: -

i) Spray 0.02% Cypermethrin or 0.02% Decamethrin or 0.05% Quinolophos. At fortnightly interval.

Harvesting and Postharvest Handling

Harvesting is done in the early morning. Depending upon the varieties plant start yielding flower after 3-4 months of transplanting. For cut flower purpose, stem is cut about 10 cm above the soil to avoid cutting into wooden tissue. The lower $^1/_3$ of stem are placed in water to extend the vase life of cut flowers. The best way to protect the flowers is to sleeve the bunch with a transparent plastic sleeve. The correct stages of harvest depend up on the cultivar, marketing and purpose, etc.

Grading, Packing and Storage

Grading of flowers depends on colour, diameter of flower and on stem length. The mature chrysanthemum blooms can be wrapped in plastic sleeves and stored dry for 6-8 weeks at a temperature of 0.5^0C. Standards are placed in sleeves and packed in display boxes measuring 91 x 43 x 15 cm. For bulk packing of sprays, 10, 15, or 20 stem are placed in sleeves according to grades.

Pot-mums are packed by placing them in paper or polyethylene sleeves & then in cardboard boxes in groups of six. Loose flowers are packed in bamboo baskets or gunny bags for marketing. The capacity of bamboo baskets ranges from 1 to 7 kg while gunny bags can accommodate 30 kg of loose flowers.

Yield: The natural blooming seasons for most of the regions lasts from July to February. One can harvest the flowers around 15 times.

Conclusion

- Protected cultivation is beneficial for quality production of flowers for export.
- Lack of locally bred varieties for protected cultivation.
- Breeding of specific varieties for protected cultivation should be done.
- High cost of protected cultivation.
- Application of growth regulators has favourable response to regulate flowering as well as quality as well as quantity of flower production in chrysanthemum.

Production of Quality Planting Material under Protected Environment

C.P. Singh
Department of Horticulture, G.B.P.U.A.& T., Pantnagar-263 145 (UK)

Introduction

Healthy and good quality planting material is the foundation of successful fruit industry in the country. In view of increasing cost of labor and inputs, farming has become less remunerative. Today, farmer is in search of new alternatives, especially when several incentives under Horticulture Mission and export promotion are provided by the Government. Fruit plants yield much higher than ordinary field crops and are certainly far more remunerative. It is a healthy sign that farmers are now keen to plant more area under orchards.

It is now well established that there is a need to increase area under fruit crops, in order to step up production of fruits. In India, more than 4409 fruit nurseries including 1575 under government sector 2834 under private sector, are functioning, which have annual target of producing 1387 million fruit plants. In view of growing importance of fruit crops, the demand for quality planting material has increased manifold throughout the country in the recent past. However, the greatest bottleneck in the expansion of area under fruits is the non-availability of genuine and quality planting material in adequate quantity from reliable government nurseries. More often than not, the farmers have to get the fruit plants from unreliable sources and this practice is causing great harm to the fruit industry of the country. Some of the fruit growers, with adequate means and resources, can easily establish their own fruit nurseries with certification from a recognized government agency. Setting up of a fruit nursery is a long term venture and needs lot of planning and expertise. Mistakes committed initially on any aspect like selection of soil, raising of right kind of cultivars/varieties, plant protection measure, etc., reduce the financial returns greatly form the investment, besides wastage of time and energy. So, careful planning is needed before setting up a nursery. The plan should show allocation of plots/area to different components of the nursery such as mother plants of different fruits/cultivars, rootstocks, roads/paths, water channels, drainage system, buildings/other structures, etc. Provision of certain basic pre-requisites is a must for raising a fruit nursery on modern lines.

The vegetative propagation of fruit crops makes them vulnerable to transmission of several diseases and pests through the planting material. Thus, importance of testing of material in the process of its preparation at various stages needs due attention. The targets of the enhancing fruit production in the coming years will be achieved only through production and distribution of healthy, genuine and high quality planting material of commercial/improved varieties of fruit crops in sufficient quantities. The maintenance of purity is easy in vegetatively propagated fruit crops as compared to seed propagated ones, still it requires a close monitoring at different stages in the nursery to avoid mixing with other varieties. Similarly, adequate measures are taken in the preparation of plant material to produce disease and pest free plant material.

Progeny Trees/Mother Plants

The bud sticks/graft wood should always be taken from healthy and true to type progeny trees of commercial/new varieties, which are free from viruses, disease and pest occurrence. A nurseryman should have progeny trees of all the promising cultivars of fruits that can be grown in that particular area.

Mother Plant Selection and Maintenance

Mother plant is the most important factor of plant nursery. Mother plants provide bud sticks and scions for budding and grafting operations.

Criteria for Selection of Mother Plants

1. Mother plants should be vigorous, healthy and high yielding. It should have a regular bearing habit.
2. It should be free from pests, diseases and viruses.
3. The mother plants must necessarily be genetically pure and superior in quality. They must be obtained from Registered Farms, Agriculture Universities or Government Nurseries.
4. The purchase receipt of mother plant should be preserved to prove the origin and authenticity of the mother plants.
5. Mother plants should be selected corresponding to the regional demand of the nursery plants.
6. Ornamental mother plants are planted under protected conditions either under shade net or semi-shade conditions.

Planting of Mother Plants

Proper selection is very necessary for mother plants. By considering its quantitative and qualitative characters, mother plants are selected and planted in nursery. They are planted according to the recommended planting distance. Care should be taken that the mother plants attain optimum vegetative growth. Mother plant plantation must be well classified according to the types and varieties.

Maintenance of Mother Plant

Mother plants are very important constituent of a nursery. The success of any nursery depends greatly on the health and vigor of its mother plants. It is therefore necessary to obtain genetically sound mother plants to produce healthy and vigorous off springs. Not only is the selection of mother plants necessary but proper care and maintenance of these plants is also essential to obtain vigorous and healthy growth. This can be achieved by taking appropriate care. Mother plants are irrigated regularly. Manures and Fertilizers are given at proper stages. Diseases and pests are controlled by spraying fungicides and insecticides. After care and all operations are carried out so as to get healthy and vigorous bud sticks. First dose of manures and fertilizers is given in June – July. Second dose is given in September – October. Reproductive growth is strictly avoided. Only vegetative growth is permitted and maximum bud sticks are produced. Mother

plants are kept healthy by regular testing of the plant material for viruses and other organisms. Register record about parents, pedigree and bearing habit is kept in office.

Propagation Structures:

Propagation structures are very essential for production of grafts or seedlings. They are useful for multiplication of grafts and seedlings. Hardening of plants is done with the help of propagation structures

Plant Propagation Structures

Structures that are used for propagating plants by seed, cuttings, and grafting.

1. One structure is designed for temperature and light control where seeds are germinated, cuttings rooted, or tissue cultured plants develop roots and leaves. Greenhouses and Quonset frames are used for this purpose.
2. The other structure is constructed to acclimatize young, tender liner plants. Cold frames low polyethylene tunnels, sun tunnels and shade houses are used for this purpose.

Tissue Culture Facilities : A unit that consist of separate preparation, transfer, and growing areas designed to develop and harden tissue cultured plants.

- **Greenhouses**: structures that are used for the production of pot plants, foliage plants, bedding plants, and cut flowers.

Types:

1. **Gable-roof construction** (it has more expensive, reinforced support for hanging mist systems, supplementary lightings, or additional tiers of potted plants.)
2. **Retractable roof** (it has a roof that can be opened during the day and closed at night.)
3. **Quonset-type** (it is inexpensive propagation house made of bend tubing or PVC frame that is covered with polyethylene.)

- **Hot Frames and Tunnels** (they are similar in function as a greenhouse and may consist of a wooden box or frame with a sloping, tight-fitting lip made of window sash. A tunnel is made from hoped metal tubing or bent PVC pipe, which is covered with polyethylene plastic sheets.)
- **Lath house or shade house** (same as greenhouses except on tissue culturing). It provides outdoor shade and protects container stock from high summer temperatures and high light intensity.

Greenhouse Covering Materials

1. **Glass** – It is more expensive than plastic coverings, yet for a permanent installation, glass may be more satisfactory than others. Glass is superior to plastic coverings in light transmitting properties and lower relative humidity problems.
2. **Flexible covering material** – Polyethylene is a low-cost plastic for covering propagation structures. Use 4-6 mils for best results.

3. **Rigid covering material** - Acrylic (Plexi glass, Lucite, Exolite) is a highly weather resistant material, has excellent light transmission properties, retains twice the heat of glass, and is very resistant to impact, but is brittle.
4. **Polycarbonate** – This material is similar to acrylic in heat retention properties, with about 90 percent of the light transmission of glass.
5. **Fiberglass** – a corrugated or flat resin reinforced with fiberglass is long lasting, lightweight, and easily applied.

Containers for Propagation

- Flats – Shallow plastic, Styrofoam, wooden, or metal trays. Used for seed germination or stem rooting. The 11 x 21 inch plastic flats are the industry standard
- Clay Pots – These are used for growing young plants. They are easily broken, and accumulate salts and calcium on the clay surface.
- Plastic Pots – lightweight, reusable, round or square containers used for the propagation of seeds, bedding, and flowering plants.
- Fiber Pots – Round or square, pressed peat or wood fiber containers. Popular because they are biodegradable and can be installed in the ground with the plant.
- Peat and Fiber Blocks – solid, pre punched containers used for germinating medium for seeds and as a rooting medium for cuttings, especially for chrysanthemums and poinsettias.
- Plastic Containers - heavy to thin-walled, black, gray or white, one , three, and five-gallon containers used for transplanting and upgrading liner stock for future growth and development.
- Polyethylene Bags – a plastic bag used for growing rooted cuttings or seedling liners to a salable size. They are considerably less expensive than rigid plastic containers and seem to be satisfactory as containers.
- Wood Containers – a square box constructed for holding large, field-grown, woody plants for several months or years.

Soil and Media Components

Soil – sand, silt, and clay

Sand – decomposed quartz particles 0.05 to 2.0 mm in diameter.

Peat Moss – decomposed bog vegetation used to hold water in soil mix

Vermiculite – a hydrated magnesium-aluminum-iron silicate mica mineral that expands when heated. Sold in four sizes: 1 (5-8 mm); 2 (2-3 mm); 3 (1-2 mm); and, 4 (0.75 – 1 mm).

Perlite - a gray-white volcanic silica material. Size range is from 1.6 to 3 mm in diameter. Low CEC and mineral content as well as fluoride production.

Pumice – Volcanic rock used in mixes to increase aeration and drainage.

Shredded Bark - wood products made from redwood, cedar, fir, pine, hemlock, or various

hardwood bark species as a component in growing and propagating mixes.

Fertilizers

Pre plant – gypsum, dolomite limestone, and microelements

Post plant – nitrogen, phosphorus, and potassium in a slow-release fertilizer form

Seedling Production using Seedling Trays:

It is already a commercial venture to produce the seedlings of tomato, capsicum, cauliflower and cabbage hybrids using seedling trays and protective structure. In the past, the farmers themselves use to produce all seedlings used for transplanting. This was all right as most of them were growing comparatively low cost open pollinated vegetable varieties. Now a days many progressive farmers are coming forward to take up quality seedling production using seedling trays and supply to the individual farmers. Even for fruit crops like papaya bigger sized trays can be used for raising the seedlings. This method is mostly adopted for raising seedlings of F1 hybrids since the cost of the seed is quite high. The vegetable seedlings are produced under protective structures such as insect proof net houses, shade houses and low cost naturally ventilated greenhouses.

Advantages of seedling rising through seedling trays:

1. Growing in seedling trays with right growing media helps in proper germination.
2. It provides independent area for each seed to germinate and grow.
3. Seedling mortality or damping off rates are reduced by using properly sterilized growing media.
4. Uniform and healthy growth of all seedlings.
5. Easy in handling and economy in transportation.
6. The use of trays results in win-win situation – as the grower gains and saves a lot on expensive seeds.
7. Root development is better and root damage while transplanting is nil. Thus better transplant establishment and crop stand.
8. Uniform and early maturity.

Protected structure for raising seedling:

The seedling trays are commonly kept under nylon net house or poly house. Net house is found to be cost effective and feasible structure to grow vegetable seedlings. Net house is commonly built using granite stone pillars. Stone pillars of 10’ x 6’’ x 4’’ are generally used. These stone pillars are spaced at 5m x 5m and grouted to a depth of 2feet. The stone pillars all along the periphery of the net house should be tied to a peg stone using guy wire. The height of the structure should be 8 feet. On top of each stone pillar used rubber tube is tied so that sharp edges of the pillars do not damage the nylon mesh and shade net. Wire grid is provided at the top of the structure as support for the nylon mesh. Normally farmers cover the sides with 40 mesh UV stabilized nylon insect proof net and in the top 50% UV stabilized HDPE shade net is used to cover the net house. It is recommended to cover the sides and top of the net house with 40 mesh UV stabilized nylon insect proof net. During summer and hot sunny days 25 % or 35% UV

stabilized HDPE shade net is spread over the nylon mesh on the top of the net house to maintain ambient temperatures suitable for crop growth. Provision should be made to pull polythene sheet over the pro-trays in the event of rainfall by way of making low tunnel structure. For preparing low tunnel structure, 3/4" HDPE pipes or bamboo stick and 400-gauge polyethylene sheet can be used. The approximate cost for building stone pillar net house will be Rs. 80 to Rs. 100 per square meter depending on the locality. Seedling rising can also be done in low cost greenhouse or wooden poly houses.

Growing media for seedling trays:

1. Sterilized commercial growing media is better as the incidence of seedling diseases is less or nil and it contain right amount of moisture in it.
2. The most common growing media used is coco peat, which is steam sterilized to prevent nursery diseases.
3. Coco peat is a by-product of coir industry and it has high water holding capacity. It should be well decomposed, sterilized and supplemented with major nutrient sources before using. Basically coconut fiber powder is low in nutrients and high in lignin content. Thus it need to be properly decomposed by adding major and micronutrients and microorganisms.
4. Other growing media which have given good result are coco peat, vermicompost and vermicompost: sand in equal proportions.

Method of seedling rising:

1. Fill the seedling tray with appropriate growing medium such as coco peat.
2. Make a small depression for sowing (0.5 cm) by fingertip in the center of the cell. Alternatively, depression can be created by stacking about 10 trays one over other and pressing the trays together.
3. Sow one seed per cell and cover by coco peat.
4. No irrigation is required before or after sowing if coco peat having 300-400 percent moisture is used.
5. Keep about 10 trays one over the other for 3 to 6 days, depending on the crops. Cover the entire stack of tray with polyethylene sheet. This arrangement ensures the conservation of moisture in the seedling trays until germination and hence no irrigation is required till seedling emergence. Care must be taken for spreading the trays when the seedling is just emerging, otherwise seedlings will get etiolated.
6. Seeds start emerging after about 3-6 days of sowing depending upon the crops. Then the trays are kept spread over a bed covered with polyethylene sheet.
7. The germinating trays are then irrigated lightly, daily depending upon the prevailing weather conditions.
8. The trays are also drenched with fungicides as a precautionary measure against seedling

mortality.

9. Seedling trays are watered daily, or as needed (not too wet or too dry) using a fine sprinkling water can with rose or with hose pipe fitted to rose.
10. Do not over irrigate the trays; if done will result in the leaching of nutrients and help in building up of diseases.
11. The media may need to be supplemented with the nutrient solution if the seedlings show deficiency symptom. Spray application 0.3 per cent (3g/litre) of 100 percent water soluble fertilizer (19 all with trace elements) twice (12 and 20 days after sowing).
12. Protect the trays from rainfall by covering the polyethylene sheets in the form of low tunnel.
13. Harden the seedlings by with holding irrigation and reducing the shade before transplanting

vi) Use of Nylon Net

It is important to have vegetable seedlings that are free of insect pests and disease problems. The earlier the plants are infected with pests or diseases, the more severe the effect on the field crop growth and yield. In this direction, growing vegetable seedling under cover using insect proof nylon net (40-50 mesh) is a good practice. Use *Casuarinas* or bamboo poles or GI pipe to support the net to be used by a small farmer. UV stabilized and properly stitched nets will last for 6-8 years.

ii) Solarization for nursery bed sterilization:

It is a method of heating soil through sunlight by covering it with transparent polythene sheet to control soil borne diseases including nematodes. This method used for the disinfection of raised nursery bed made in soil to produce healthy seedlings of vegetable. Other additional beneficial effects include control of weeds, insect pests and release of plant nutrients resulting in increased crop growth. Solarization is a non chemical alternative for disease, insect pest and weed control.

Methods of Vegetative Propagation:

Budding:

For budding, the thickness of the rootstock should be near to that of a pencil. It is better to take well swollen and unsprouted buds from leaf axils of mature one-year-old twigs of the scion variety. 'Forkert' or 'patch' methods can be used and the size of the bud wood may be nearly 2x1 cm and budded at a height of nearly 15cm above the ground level. Polythene tape can be used for keeping the buds close to the stock, about 2 weeks after budding the tape can be opened up to examine the success of the budding. After the bud starts sprouting the top portion can be cut. Depending on the type of crop ‘T’ or ‘Inverted T’ budding can also be adopted for some of the ornamental crops.

Grafting: The common method of grafting is 'inarching' or 'approach grafting'. 'Veneer' grafting has also been found to simple and successful method. For 'Veneer' grafting the scion must be taken from one-month-old shoot duly defoliated for forcing the buds. About 3-5 cm long shoot with

one or two buds is used for grafting. The percentage success during July has been recorded as 80%. In places where humidity is more than 70% or where mist chamber facility is there soft wood grafting and stone grafting can be practiced.

Points to be remembered while grafting:

1. The scions and rootstock should be preferably of the same diameter (for veneer)
2. The scions should be pre-cured
3. Grafting should be taken up when there is high humidity
4. Grafted plants are to be kept in mist if possible
5. Grafts should be labeled after grafting so that varieties are not mixed
6. Rootstock portion should be cut off after the leaves of the scion turns green.

Stooling: This method can be used for quick multiplication of desired varieties. In this method 3-4 years old plants are cut down near to the ground. When the new shoots emerge, IBA (5000ppm) is applied in lanolin in ring during July. After about 10 days soil is earthed up to cover the ringed part. By September, the rooted shoots can be separated. This method is easy and plot of 4-5 m square can yield 300 rooted shoots each year.

Air layering:

In this method, limbs of 1/2 inch or more in diameter are girdled by removing a strip of bark about one and half times the thickness of the limb. The girdled area is bound with a ball of moistened sphagnum moss several inches in diameter and 4.5 inches long which is then wrapped with a sheet of polythene paper and tied securely at each end with rubber bands or string. Usually roots begin to form in 3-5 weeks. When the roots grow through the ball of moss, the stem may be severed below the girdled area gradually. The polythene film is then removed from the rooted stem, which is then severed, potted and kept in the shade until new leaves appear. When the new growth is 6-8 inches long the plant can be hardened in full sunlight, preparatory to transplanting in the field.

Management of plants after propagation:

The propagated plants need to be hardened. It is always better to harden them in the shade net houses or climate controlled houses. If these are not available then they need to be kept in semi-shade conditions, so that there is no mortality of plants when they are taken to the main field. Timely sprays for insects and diseases need to be given after ascertaining the cause. To maintain the plants in healthy condition, it is better to given micro-nutrient sprays. However, it is also of paramount importance that the plants need to be labeled properly so that the variety is not mixed up.

Mango (*Mangifera indica* L.)

Commercial cultivars

North India: Dashehari, Langra, S.B.Chausa, Lucknow Safeda, Rataul, Gaurjeet, Bombay Green, Khasul Khas

South India : Neelum, Banglora, Mulgoa, Suvaranarekha, Banganpalli, Rumani, Raspuri, Badami

East India : Malda, Fazli, Himsagar, Kishenbhog, Gulabkhas, Jardalu

West India : Alphonso, Pairi, Malkurad, Kesar, Rajapuri, Jamadar

Improved varieties: Amrapali, Mallika, Ambika, Arka Anmol, Arka Aruna, Arka Neelkiran, Arka Puneet, Alfazli, AU Rumani, Ratna, Sindhu

Raising of rootstocks

Mango seedlings grown from stones of seedling trees are used as rootstocks. Stones should be collected from vigorous, disease free and high yielding trees of seedling mangoes during July-August. Mango seeds are recalcitrant and lose viability very soon on desiccation. If the mango stones are not sown within a few days of their removal from the fruit, they can be stored under moist condition in shade, covering with moist soil, sand or sawdust, etc. Before sowing stones should be immersed in water and floating stones should be discarded as they are not considered viable Stones are sown during in June to August, depending upon the ripening season of the mango, in beds mixed with well decomposed farm yard manure at the rate of 8-10 tones per hectare. When the seedlings attain the age of 2-3 months, they should be transplanted in well prepared beds or poly bags. After transplanting, proper care should be exercised in irrigating the young transplanted seedlings. Attack of leaf cutting insects is common during rainy season, which may affect the growth of the seedlings adversely.

Methods of propagation: Nurserymen in many of the mango growing areas still use inarching, traditional method of propagation. During past few decades, experimental results have shown that veneer grafting technique can be used with high success rate in Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Bihar. Stone (epicotyl) grafting is suitable for konkan region of Maharashtra and Coastal regions. Now-a-days softwood grafting is being used commercially for mango propagation in several parts of south India. Veneer grafting and soft wood grafting techniques can be used for large scale multiplication of mango in north India. With the use of **polyhouse and net house** structures, period of propagation can be extended easily under north Indian conditions.

Softwood grafting

The technique of softwood grafting is similar to that of cleft or wedge grafting. In this case, grafting is done on 3 month to 8 month old rootstocks. In south India, the rootstocks attain graftable thickness within 3-6 months due mild winter. In the past, this technique has been in use *in situ* orchard establishment under adverse soil and climatic conditions as the grafting operation is performed using cleft/wedge method on the newly grown top portion of the plant one year after the rootstock establishment in the field. The scion shoots of the thickness equal to that of rootstocks are defoliated 7-10 days prior to grafting. The graft should be secured firmly using 1.5 cm wide, 200-gauge polyethylene strip. July and August months with high humidity and moderate temperature are the best for the success of softwood grafting.

Veneer grafting

This method of propagation holds promise for mass scale commercial propagation. The method is simple and can be adopted with success. Eight month to one year old seedling rootstocks are suitable for this method. For conducting this grafting operation, a downward and inward 3-4 cm long cut is made in the smooth area of the stock at a height of about 20 cm. At the base of cut, a small shorter cut is given to intersect the first so as to remove the piece of wood and bark. The scion stick is given a long slanting cut on one side and a small short cut on the other so as to match the cuts of the stock. The scion is inserted in the stock so that the cambium layers come on the longer side. The graft union is then tied with polythene strip as recommended for inarching. After the scion takes and remains green for more than 10 days, the rootstock should be clipped in stages. The scion wood to be used for veneer grafting requires similar preparation. The desired shoots should be defoliated at least one week prior to grafting so that the dormant buds in the leaf axils become swollen.

Stone or epicotyl grafting

Mango is generally propagated by inarching and veneer grafting in north India. These methods are time consuming. Stone/ epicotyl grafting is a technique of faster multiplication of mango. This method is simple, economic and fast. Fresh mango stones are sown in the nursery beds. After germination, 10-15 day old seedlings with tender stems and coppery leaves are lifted with along with stones. The roots and stones are dipped into 0.1 per cent carbendazim solution for 5 minutes after washing the soil. The seedling stems are headed back leaving 6-8 cm long stem. A 3-4.5 cm longitudinal cut is made into the middle portion of the cut stem. A wedge shaped cut starting on both sides is made on the lower part of scion stick. The scion stick should be 4-5 months old and 10-15 cm long containing plumpy terminal buds. The scion stick is then inserted in the cleft of the seedlings and tied with polythene strip. The grafts are then planted in polyethylene bags containing potting mixture. The bags are then kept in the shade protecting from heavy rain. When the scion sprouts and the leaves become green, the grafted plants should be planted in nursery beds. July is the most suitable month for stone grafting.

Care of nursery plants : Mango plants at nursery stage are likely to be damaged by frost under north Indian conditions. So, the nursery beds should be covered with thatches made of sarkanda etc. The beds should be irrigated whenever there is danger of frost. During summer, the irrigation should be given at 4-5 day intervals depending upon the soil condition. A light application of Calcium Ammonium Nitrate or Ammonium sulphate is also recommended to encourage the growth of plants. The beds/ poly bags should be kept free from weeds by regular weeding/hoeing.

Plant Protection Measures

Insect pests

Mango hopper (*Idioscopus spp.* and *Amritodus atkinsoni*): It is active in February –March. The nymphs and adults such the juice from tender leaves. For control, 2-3 sprays of 0.04 %

monocrotophos is recommended.

Diseases

Mango malformation (Bunchy top): On seedlings, over three months old, swelling appears in the axils of leaves. The affected plants should immediately be uprooted and destroyed. Such seedlings should not be used for rootstocks.

Guava (*Psidium guajava* L.)

Commercial cultivars: Allahabad Safeda, Sardar Guava (L-49)

Improved cultivars :Lalit, Shweta, Arka Mridula, Arka Amulya, Dharidar, Kohir Safeda, Pant Prabhat, Safed Jam

Raising of rootstocks

Raising rootstocks in polyethylene bags is recommended as this give better establishment of plants in the field on account of undisturbed tap root system. Moreover, nursery raising in polyethylene bags saves labor in weeding, watering, shifting and lifting of plants. The chief advantage of using polyethylene bags is that, the seedlings can be raised almost round the year under controlled conditions. Guava seeds have a hard coating over the endocarp as a result of which usually long time is required for germination. Fresh seeds should be extracted from fruits and washed thoroughly to remove the pulpy material clinging to the seeds. It should be treated with fungicide (copper oxy chloride) to prevent damping-off of seedling before sowing in the polyethylene bag. If the damping-off occurs as the seedlings emerge, both the seedlings and the media should be treated with a fungicide. A group of fungi is responsible for damping off of the seedlings. For controlling damping off, treatment with 0.3% copper oxy chloride has been found very effective. Seeds of guava are sown in polyethylene bags (20x10 cm or 18x27cm) at any time (January-December).Polyethylene bags are filled with soil, sand and farmyard manures in 3:1:1 ratio. All the polyethylene bags are covered with 100 micron (400 gauge) white polyethylene sheet soon after sowing of seed. During winter months, the polyethylene mulch conserves heat and create conducive environment (microclimate) for rapid germination and early establishment of seedlings. Seed covered with polyethylene sheet gives as high as 97 per cent success within three weeks.

Patch Budding

Seedlings of about one year age, pencil thick, uniform and active in growth are selected. This method is most satisfactory when vigorously growing plants with 1.25-2.5 cm in stem diameter, are used as stock. The trees from which buds are taken should be highly vegetative with lush succulent growth to permit easy separation of buds from the stem. It is better to take swollen and un sprouted dormant buds from leaf axil of mature twigs of the scion variety. A patch, approximately 1 cm (0.5 inch) to 1.5 cm (0.75 inch) with a bud seems to be taken for better success. Similarly, 1-1.5 cm long patch is removed from the rootstock and bud is fitted into the remaining portion on the stock seedling. Bud should be fitted at a height of nearly 15 cm above the

ground level. Polyethylene strip is used for keeping the buds close to the stock. When the bark adheres tightly to the wood, budding is usually successful. After about 2-3 weeks of budding the polyethylene strip can be opened to examine the success.

Stooling

Stooling is the easiest and cheapest method of guava propagation. This method can be used for quick multiplication of desired varieties and also rootstocks. In this method, self-rooted plants (cuttings and layers) are planted 0.5 m apart in the stooling bed. These are allowed to grow for about three years. Then these are cut down at the ground level in March. New shoots emerge on the be headed stumps.A 30-cm wide ring of bark is removed from the base of each shoot rubbing the cambium of the exposed portion in May. All the shoots are mounted with the soil to a height of 30 cm. The soil is covered with mulch to conserve the moisture. After a period of two months of the onset of monsoon, the shoots are detached from the mother plant at ringed portion and planted in the nursery. The shoots are headed back to maintain the root and shoot balance before planting in the nursery by following the technique of ringing and mounding of the shoots, second time stooling is done on the same mother shoot in the first week of September.

Air layering

Air layering is one of the most important commercial method in practice for guava propagation. Rainy season (preferably July-August) is the most suitable period for air layering. In this method, limbs of about 1.2cm or more in diameter are girdled by removing a strip of bark with a width of about 2cm. The girdled area is bound with a ball of moistened sphagnum moss of about 7 cm in diameter and 10-13cm long, which is then wrapped with polyethylene film and tied loosely over the wrap to prevent bird damage and also to prevent the moistened moss from overheating. Roots usually start developing in three to five weeks. When they grow through the ball of moss, the stem may be detached from the mother plant below the girdled area. The polyethylene film is removed and the new plant is potted in manured soil in pot/polyethylene bags and kept in the shade until new leaves appear.

Soft-wood /Wedge grafting

Soft-wood /Wedge grafting, a technique for rapid multiplication has been perfected at Central Institute for Subtropical Horticulture (CISH), Lucknow. This technique has a tremendous potential for multiplying guava plants rapidly throughout the year both in greenhouse and under open conditions. Presently, the institute is producing quality materials of guava through wedge grafting technique round the year in greenhouse as well as in open conditions. The technique involves growing of seedlings in polyethylene bags, grafting, capping and hardening of grafts. Seedlings are raised for rootstocks in the nursery for approximately 6 to 8 months. When the stem diameter of seedling is of pencil thickness (0.5-1.0 cm) they are chosen for wedge grafting. In this technique, proper selection and preparation of scion sticks is very important for obtaining higher success. Shoot with growing apical portion (terminal growth) which is 3 to 4 months old is ideal for

this technique. The scion shoot of pencil thickness, with 3 to 4 healthy buds of 15-18 cm long is used for grafting. Selected scion shoots are defoliated on the mother plant, about 5-7 days prior to detaching. At the same time, the apical growing portion of selected shoot is also beheaded. This helps in forcing the dormant buds to swell. In this way, the buds on the scion are ready to start sprouting at the time of grafting. This treatment is essential for high success of grafts. After selection of the scion, rootstock (seedling) is headed back by retaining 15-18 cm long stem above the soil level in the polyethylene bag. The beheaded rootstock is split to about 4.0 - 4.5 cm deep through the centre of the stem with grafting knife. A wedge shaped cut, slanting from both the sides (4.0 -4.5 cm long) is made on the lower side of the scion shoot. Care must be exercised to match the cambium layer of the stock and scion along with full length of each component. The union is then tied with the help of 150 gauge polyethylene strip, 2 cm in width and 25 - 30 cm in length. Immediately after grafting, the graft is covered by 2.5 x 18.0 cm long white polyethylene cap which is tied with rubber band at the lower end.

Aonla (*Emblicaofficinalis* Gaertn)

Commercial Cultivars : Chakiya, Kanchan, Krishna, Narendra Aonla-6, Narendra Aonla-7, Narendra Aonla-10

Raising of rootstocks

Aonla is commercially propagated by budding/ grafting on seedling rootstock. Fruits are collected from local seedling (desi) aonla trees and used for rootstock raising. Mature fruits should be collected during January/February. Fruits are dried in open and seeds are extracted by applying light pressure. One kg seed can be obtained from one quintal of desi aonla fruits. Raising of seedling is essential for rootstock. The timing for sowing of seed has been standardized. Sowing of seed on raised bed (after soaking in water for 12 hours) or in poly bag during March/ April facilitates quick germination. Germination of seeds of aonla is better during March-April and July-September.

Patch Budding

Six months to one-year old seedlings are used as rootstock for budding. The scion shoots should be selected from the mother plants, which are prolific bearers and free from disease and pest incidence. Patch/ modified ring budding during mid of May to September gives 60 to 90 per cent success under north Indian conditions. However, in south India, aonla propagation is being done almost 8-10 months in a year with the aid of greenhouse and net house facilities. Besides budding, veneer and soft wood grafting are also successfully attempted with about 70 per cent success. However, considering the efficiency, budding appears to be an ideal method for aonla propagation. Propagation of aonla in poly bags/poly tubes, or *in situ* orchard establishment (particularly in the drier areas) have been standardized and needs popularization. Aonla scion shoots can safely be stored/ transported in sphagnum moss / moist newspaper for 5-7 days with ample success.

Soft wood/Wedge grafting

When the seedling attains pencil thickness, it is ready for grafting. The top of the rootstock is cut off at the height of 15-18 cm from the surface of poly bag or ground. Splitting the be headed rootstock vertically down the center, to a point 4 to 5 cm below the cut surface. Scion stick is collected from desired variety. The shoot with 6 to 8 healthy buds, 12 to 18 cm long pencil thick is cut from the selected mother plant. Scion stick should be cut from both sides into a tapering wedge approximately 4 to 5 cm long. The tapered end is inserted into the split stem of the rootstock. The rootstock and scion are wrapped tightly with 2 cm wide and 25 to 30 cm in length polyethylene strip. Immediately after grafting, the scion is covered with poly cap. Within 12 to 15 days of grafting scion shoots sprout, which is visible from outside. The poly caps are carefully removed after 21 days and these are kept for hardening. Early removal of poly caps results in high mortality. Winter months suitable for wedge grafting in the field conditions, while round the year can be grafted in greenhouse. Field transferable grafts become ready within 6-8 months of seed sowing.

Good Nursery Practices to Raise Disease - Free

Plants of Citrus

NRC for Citrus, Nagpur has taken a mission oriented programme on production of disease free planting material of Nagpur mandarin, acid lime and sweet orange (Mosambi) by adopting the most advanced and internationally accepted techniques of nursery management duly standardized at the Centre (Singh *et a*l.) The disease free (from virus and fungal diseases) plants were raised to supply to Government owned nurseries for raising mother plants and to the citrus growers to overcome the problem of citrus decline. The techniques adopted in production of disease free planting material are briefed here (Singh, 1999).

Containerised Nursery System

In India most of the citrus nurseries are grown as field nursery. In field nurseries, the eradication of soil borne pathogens like *Phytophthora* once introduced becomes very difficult. To avoid this problem, concept of containerized nursery system was adopted. The infrastructure required for such nurseries includes shade net houses (50 % shade), sterilized plastic trays, UV stabilized black poly bags (100 µ), UV stabilized transparent polythene for solarization, fumigation of potting mixture, a separate set of nursery equipments etc.

Potting mixture: The potting mixture, consisting one part of virgin fertile soil + sand +FYM (sterilized), was used in plastic trays for seed sowing in primary nursery. The same sterilized mixture was used for filling the polybags to be used in secondary nursery.

A. Soil Solarization: The potting mixture was first collected on a concrete floor and spread in the form of flat bed of 1.5' thick layer. These beds were completely drenched with water before covering it with 100 µ UV stabilized transparent polythene sheets in summer months (April- May) when atmospheric temperature goes up to 45 – 46 ^{0}C. The edges of polythene sheet were completely sealed with soil to avoid vapour loss, which allowed the inside temperature to rise upto 54^{o}C. Soil solarization was done for 4 – 6 weeks.

B. Soil fumigation: The solarized soil was further fumigated with Basamid (Dazomet) granules, a soil fumigant, which releases methyl iso cyanide gas and thereby, completely eliminates *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp. and *Fusarium* spp.from the soil. Solarised and fumigated potting mixture was used to fill trays and bags.

C. Steam sterilisation

This is one of the quickest method of potting mixture sterilization. In this method steam are passed through potting mixture which kills all pathogen and weeds. First mixture was filled in jeep trolley which have nozzle in bottom of trolley. Then steam which is generated in boiler passed in this covered trolley for about 20 minute.

Selection of seed

Seed should be collected from healthy fruits of recommended cultivars /rootstocks. Only selected trees free from diseases should be used as seed source. Fruit that has fallen is more subject to brown rot infection. Seed in rotten fruit may be invaded by fungi that later contaminate the seedling. Seeds are extracted from fully ripened fruits by making a shallow cut through the rind round the centre of the fruit and twisting the two halves of fruit apart. Seeds are then washed into cold water with rubbing in ash to make tree from pulp and dried under shade condition. The sound seeds, being of greater density are separated from the underdeveloped seeds. The number of seeds per fruit varies in citrus species and cultivars. The seeds of most citrus spp. are recalcitrant. Their viability during storage varies depending upon species and storage conditions. Serious loss of seedlings in the seed bed and nursery from infection of fungi *Phytophthora* have been reported. Therefore seed should be treated with a fungicide like bavistin to reduce the infection. Seeds should be sown as early as possible after extraction, since citrus seeds give the highest germination if planted immediately after extraction.

Role of rootstock

In our county citrus trees are propagated by vegetative as well as by seeds. Propagation by budding should be encouraged particularly for sweet orange and mandarin. Since budded plants come early in bearing (4-5th year) than seedling plants (9-10 years). Using rootstock exert profound influence on the vigour, productivity, quality of fruits, longevity of the scion, adaptability to soil climatic conditions , etc and also response to different pest and diseases. It is therefore, important to appreciate the need for using the appropriate rootstock suiting to a particular location so that the threat of dieback can be minimized. The selection of proper rootstocks for different regions is quite complicated and required serious attention. However in our country rough lemon and Rangpur lime are commercially used as rootstock for different mandarin and sweet orange cultivars.

Raising of seedling in primary nursery

For raising disease- free nursery it is required to grow primary nursery in tray. Since most of the citrus nurseries are reported to be infected with *Phytophthora*). Plastic tray 60x40x12 cm

size was found ideal for primary nursery. After making 6 holes in bottom of trays to drain out excess water, trays are filled with sterilized potting mixture (One part fertile soil + one part sand + one part FYM) and trays are kept at 1.5 feet height from the ground on the bricks or on cement platform to check the contamination. After leveling the mixture up to top level of trays seeds are sown at depth of 1- 1.5 cm with spacing 2.5 to 3.0cm in the row and after sowing light shower irrigation should be done with a water can. The germination starts within 20-25 days after seed sowing depending upon the rootstocks. Citrus seeds usually germinate at a soil temperature above 55 ^{0} F. The optimum temperature is between 80 and 90 ^{o} F. It is necessary to protect the primary nursery with some type of shelter. Both intense sun and wind may cause emerging seedlings to burn. The shade net (50 % shade) was found ideal for citrus seedlings. Irrigation of seedlings is most critical aspect. Germinating seeds are quickly killed by drought and on other hand, excessive moisture favours the development of damping off fungus. Therefore, frequent and light watering is required for newly planted seed beds.

Transplanting of seedling in secondary nursery

Seedling when 4 to 6" tall having 8 to 10 leaves are transplanted to black polythene bag of 12" to 6" size having 3-4 holes at the bottom to drain out excess water. The polythene bags are filled with sterilized potting mixture and arranged in shade net. To ensure uniform nucellar seedlings, discard of markedly smaller or too taller ones at the time of transplanting. Seedlings from primary nursery (Trays) should be uprooted with fork carefully to minimize root damage. The hook-necked bent or twisted taproot seedlings should be avoided. Selected seedling should be treated with Ridomil (2.75g /litre water) solution before transplanting to check the contamination at the time of transplanting. The seedlings are transplanted in the month of July-Aug after commencement of monsoon. The holes in which the seedlings are to be planted are usually made by stick. The roots of the seedling are then placed in the opening and pressing the soil firmly around the seedling to make contact of soil with roots for quick and better establishment. Irrigation should follow the planting of seedlings. In the beginning water should be applied frequently to overcome the shock of transplanting. The nursery must be kept free from weeds at all times. The side shoots should be removed regularly to develop single straight stem. Frequent and light irrigation should be given as per need taking care to avoid water stagnation in polythene bags. If such bags found excess water may drain out through making the new holes in polythene bags.

Selection of mother plants and bud wood:

Selection of mother plants for bud wood is the most critical parts of production of disease-free planting material. Since plant productivity, longevity, fruit quality and most important free from diseases all depend on types of mother plants. Therefore mother plants should be selected from authentic sources with known pedigree in respect to health, vigor, regular bearing and high yield with good quality fruit. Selected plants should be indexed against diseases (viruses and Greening bacterium) and only disease free plants should be used as bud source. Such disease-free plants

should be marked and bud stick should be carefully taken to avoid infection. For this purpose knife used should be disinfected with alcohol or sodium hypochlorite solution. Bud wood should be always taken from fairly well matured wood of current season growth or next to last growth. Round twigs having longitudinal white streak on the bark, swollen buds ready to grow should be selected. First one or two basal buds, which are usually somewhat imperfect, should be discarded. Bud wood should be kept in moist sphagnum moss and gunny bag to avoid exposure desiccation.

DIAGNOSIS OF VIRUS/VIRUS LIKE DISEASES

- The virus detection tests were performed for the disease status of mother plants.
- More than fifteen virus and virus like pathogens have been reported to attack citrus in India.
- Samples were taken from these identified elite mother plants for biological/serological detection against major pathogens *viz*., citrus tristeza virus, citrus mosaic, citrus ring spot, citrus exocortis, viroid and greening bacterium.

i. Serological diagnosis:

Serological indexing was done in DAS-ELISA by using monoclonal (CTV) and polyclonal (CTV, RS, mosaic) antibodies.

ii. Bo-diagnosis:

The biological indexing was also performed simultaneously using indicator plants like acid lime for tristeza, sweet orange for greening bacterium and mosaic virus, citron for exocortis and sweet orange and *Chenopodium quinoa* for ring spot etc. under insect proof controlled conditions. Thus, the virus free plants among selected elite mother plants were identified for further multiplication.

Budding and maintenance of budlings

Budding should be done in the season when bark would slip. The time of budding effects bud take and subsequent growth of plants. October is the best time for budding pineapple sweet orange on *C. jambhiri* rootstock under Delhi condition. In Vidarbha region of Maharashtra budding is usually done in Nov- Jan when seedling attain the girth of 3.0 to 3.5cm at 9" height from ground level following the 'T' or shield budding method. The budded portion should be wrapped with 100 guage polythene strips of 1.2-1.8 cm wide.

Plant protection measures

In citrus nurseries, *Phytophthora* diseases may appear any time of plant growth through contaminated water, soil and even through nursery workers and implements. Therefore a regular monitoring should be done for *Phytophthora* infection. In case of infection, the infected/contaminated plants should immediately uprooted and destroyed to keep the nursery totally free from *Phytophthora* and other diseases. The nursery plants are sprayed with Bavistin @ 1 g/lit water at monthly interval as a prophylactic measure. If plants affected by *Phytophthora* spp. are noticed, remove the affected plants with polythene bags and spray Ridomil MZ 72 @ 2.75 g

OR Aliette @2.5 g/lit. Nursery implements should be disinfected regularly with sodium hypochloride solution and at the entry of nursery. The arrangement should made to disinfect the shoe of workers and visitors with copper sulphate and lime dust. Floor should be regularly sprayed with copper fungicides and at the entrance of nursery. The insect pests in nursery should be managed with the regular application of recommended insecticides

- Monocrotophos @ 1.0 ml /lit. water against leaf miner
- Confidor @ 0.5 ml/lit. water against leaf eating caterpillar/ Thrips
- Nuvan @ 1.5 ml/ lit. water against leaf miner
- Quinalphos @ 1.0 ml/lit. water against aphids
- Dicofol (kelthane) @ 1.5 ml/lit. water or wettable sulphur @ 3 g/lit.water against mites
- Neem oil (1 %) spray when rotated with foliar sprays of any of the above pesticides gave better results against insect pests.

Tips for raising disease- free nursery

- Nursery site should be away from the citrus orchards.
- Nursery should be raised in containers (plastic trays/polythene bags)
- Only sterilized potting mixture should be used in primary and secondary nursery.
- Always use fresh seeds extracted from healthy fruits and sow in trays under shade conditions for better germination
- Seed trays must be kept at least 1.5- 2.0' above the ground to avoid soil borne contamination.
- Nursery floor should be covered with stones/ stone dust to avoid contamination from soil.
- Only nucellar seedlings should be selected for further growth.
- Seedlings with bent and twisted tap root system should be discarded
- Too long taproot should be cut to ensure the straight penetration of root in soil.
- Seedlings should be transplanted during rainy season/cloudy days in polythene bags for greater survival.
- Seedlings should be treated with Ridomil @ 2.75g and Bavistin @ 1g/lit water at the time of transplanting in secondary nursery.
- Bud wood should be taken from disease free selected and certified elite mother plants of known pedigree.
- High budding not less than 9" of height should be done.
- Sterilized knife with alcohol or sodium hypo chloride should be used for budding and it should regularly be washed with surface disinfectant.
- Bud wood should be selected from fairly well mature non-bearing shoots of current year growth from selected plants.
- Selected mother plants should be monitored regularly for diseases.

- Regular recommended plant protection measures should be followed to control insect pests.
- Prophylactic measures should be taken against diseases and diseased plants should be destroyed.
- Set of nursery implements and workers should be separate.
- The entry of visitors should be restricted in disease- free area of nursery to avoid contamination.
- The arrangement should be made to disinfect the shoe of workers and visitors with copper sulphate and lime dust at the entry of nursery.

Conclusion

Overlooking the state of the art as discussed above our conclusion is that production of planting material can be realistic if the following aspects will be taken into account as part of an optimized strategy for the organic propagation of seed and planting material:

- Selecting and developing cultivars with sufficient tolerance or resistance against diseases during production of planting material is crucial;
- Further practical and research work is needed to improve and adapt cultural practices for the production of healthy organic seed and planting material;
- Seed and planting material producers should identify the best locations in terms of a low disease pressure;
- Practical seed health tests and standards should be developed for crops with a high risk of seed-borne diseases;
- Adequate, alternative seed treatment techniques need to be developed, and legislated;
- For the successful development of a seed and planting material production system, good communication and mutual commitment from farmers, traders, breeders and governments are necessary.

Commercial Aspect of Biocontrol of Pest & Diseases

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

The goal of biocontrol research is to provide additional tools for disease management. To place these tools in the growers' hands, products must be commercialized. The Bio-pesticide market is growing very rapidly. In 2005, bio-pesticides accounted for about 2.5% of the total pesticide market, which was merely 0.2% during 2000. This share is expected to grow to about 5.2% by 2012. The contributions of bio-pesticides are important because, they offer different modes of action from chemical pesticides and can, therefore, be applied in rotation with pesticides to reduce the possible development of pathogen resistance; pathogen resistance to fungicides has promoted interest in development of biocontrol agents; biocontrol can also be used in situations where currently no control is available or where conventional pesticides cannot be used due to reentry or residue concerns, or where the product must be certified organic; biocontrol can also be used in combination with reduced rates of pesticides. The relevance of biocontrol agents in plant pathology is still limited in spite of the great enthusiasm generated by researchers on bio-pesticides. It is due to over optimistic published papers on the subject; over emphasis of several partial results; exaggerated claims in the literature have over shadowed problems; most of scientific reports are focused on selection of strains and basic biochemical studies and priority issues as mass production, formulation of biocontrol agents, toxicological and environmental safety and integration into other control strategies are not completely developed. These must be identified and solved by the researchers if BCAs have to find their rightful place among the different strategies of plant disease control. Biocontrol agents fail to become commercial products as scientists outside industry often overestimate the power of environmental concerns as economic drivers; lack sufficient knowledge of grower needs, registration strategy and competitive forces; have native ideas about positioning and market strategy; underestimate registration costs and difficulties and insufficient cost-performance and poor shelf life.

Commercialization of bio-pesticides is a multi-step process involving a wide range of activities. Broadly it falls into 3 main categories i.e. discoveries, development and registration. Most of the potentially useful microbial pesticides have been discovered by the scientists who have studied on a particular problem at site location in search of indigenous biocontrol agents. Presently industries do not develop the resources or incentives to discover a biocontrol agent in this manner. Therefore, the universities, government agencies and research foundation must play a significant role in the discovery of biocontrol agents. Once a biocontrol agent is identified with potential for commercialization, it enters the next phase towards commercialization, i.e. development phase.

The development phase involves tests for efficacy, safety, specificity, test for genetic stability, potential for mass production, formulation, stability and shelf-life, delivery system,

compatibility with other pesticides and plant protection equipments and the economic analysis. The most critical stage in developing a bio-pesticide is the mass production and formulation of the biocontrol agent, because it represents a living system which must stand with appropriate CUF during the process of development and remain sufficiently viable in the final product for effective management of diseases. The basic requirement for mass production of an antagonist is to standardize the nutritional requirements and cultural conditions which differ not only from one group of organism to the other, but from species to species, and even with strains/isolates within the same species. The formulation of a biocontrol agent is as critical as its mass production. While formulating a bio-pesticide, the adjuvant should not be toxic to biocontrol agent; the physical manipulation done during formulation should have no adverse effect on the viability of the organism; a food base may be required to be added which helps in initial establishment of some of the biocontrol agents; should have the CFU of at least $2x10^6$/g or ml with shelf-life of at least six months. easy to apply and survive in the field during the entire cropping season or at least at susceptible stage of the plant even under adverse conditions.

Bio-pesticides falls under the Insecticide Act (1968) under which any microbial organism manufactured or sold for pest and disease control should be registered with the Central Insecticides Board (CIB) of the Ministry of Agriculture and license for their manufacture, formulation and sale are dealt with at the State level. CIB advises the Central Government and State Governments on technical matters on which the Board may advise, the risk to human being or animals involved in the use of bio-pesticides and the safety measures necessary to prevent such risk and. the manufacture, sale, storage, transport and distribution of bio-pesticides with a view to ensure safety to human beings or animals. Manufacturers can register their products under either 9(3) B (temporary registration for two years and can be extended further for one year) or 9(3) (regular registration). The data requirement for registration under 9(3) B is less stringent than for 9(3). Data on product characterization, efficacy, safety, toxicology, and labeling must be submitted, while applying for registration. The quality standards of bio-pesticides established by CIB's must be met, with reference to content, virulence of the organism in terms of LD 50, moisture content, shelf life, and secondary non-pathogenic microbial load. Information required for registration of bio-pesticide are, systemic name and common name, natural occurrence, morphological description, details of manufacturing process, active and inert ingredient of formulation, test method used, quantitative analysis (including cfu in selective media), details of moisture content, shelf-life, mammalian toxicity, environmental toxicity and residue analysis.

In order to satisfy the commercial requirements, a bio-pesticide should have, viable market size, high performance with persistence of effect, safety and stability, indigenous and saprophytic, low cost of production, easy to produce, easy to apply and compatible with conventional technology as well chemical pesticides.

The biocontrol still represents a very small portion of disease management. If the goal of

biocontrol research is to place biocontrol products in the growers' hands, then perhaps there needs to be more communication between public researchers and industry in the early stages of development. Research is needed in many areas, particular in mass production, formulation, and delivery could greatly assist in commercialization of biocontrol agents. More research is needed in integrating biocontrol agents into production systems, such as in rotating biocontrol with chemical pesticides and in calculating these into forecast models to choose whether to apply a chemical pesticide or biocontrol. Continued research in biocontrol is needed to contribute to the movement toward sustainable agriculture and simply to ensure that alternatives are available if other management tools fail or are lost. Research on biological control of plant diseases has resulted in the selection of large numbers of micro-organisms with high potential as biological control agents against plant diseases and it could lead to alternative strategy of plant disease control. Whether these research results can be transformed into economically viable tools for agriculture will now depend on the ability of researchers to attract the interest of industry.

The guidelines / data requirements and minimum infrastructure facilities to be created by the manufacturers of microbial bio-pesticides (Antagonistic fungi, Entomopathogenic fungi, Antagonistic bacteria, Entomotoxic bacteria) for their registration under section 9(3b) and 9(3) of the insecticide act, 1968 can be uploaded from the website of Central Insecticides Board (CIB) of the Ministry of Agriculture.

Production and Management of Cucurbits in Green House

Dinesh K. Singh
Department of Vegetable Science, G.B.P.U.A.&T., Pantnagar- 263 145 (UK)

There has been paradigm shift in farmer's perception from production to productivity and to profitability. In the present scenario, the major challenges arising are shrinking land, depleting water and other related resources in agriculture. With the increasing population, urbanization and continuous depletion of natural resources there is a need for promoting farmers friendly location specific production system management technologies in a concerted manner to achieve a vertical growth in horticulture production ensuring quality of produce and better remuneration per unit area with judicious use of nature resources. In this endeavor, protected cultivation aims to have efficient utilization of resources per unit of time and area for achieving targeted production of horticulture produce.

The vegetables of the family Cucurbitaceae are known as 'Cucurbit vegetables' and they constitute the largest group of summer vegetables. These crops supply man with edible food, fiber and fodder. Cucumber and gherkins are being extensively grown in green houses in many countries. Cucurbits like bottle gourd, bitter gourd, ridge gourd, water melon and musk melon may also be grown in polyhouses, during off season based on location specific needs. The crops produced in green houses fetch higher income due to good quality produce and higher productivity per unit area as also due to being, available in off season. The cropping period gets extended so, regular supply could be maintained for a long time. In general the crops like cucumber, bitter gourd and bottle gourd continue for about 6 months in naturally ventilated polyhouses.

Polyhouses are highly suitable for off-season cultivation of cucurbits and are also highly economical for peri-urban areas of northern plains of India. Naturally ventilated greenhouses are highly suitable for year-round parthenocarpic cucumber cultivation, whereas, walk-in-tunnels are suitable for off-season cultivation of melons. Plastic low tunnels are highly suitable and profitable for off-season cultivation of cucurbits like summer squash, bottle gourd, bitter gourd, muskmelon, watermelon, round melon and long melon in peri-urban areas of northern plains of India.

Parthenocarpic cucumber

Parthenocarpic cucumber is a high value vegetable crop immensely suited for off season purpose under polyhouse cultivation. Parthenocarpy is the ability to develop fruits without pollination. The fruits are therefore seedless. The inheritance of parthenocarpy in cucumber is controlled by an incomplete dominant gene Pc. The fruit of Parthenocarpic cucumber are mild in flavor, seedless and have edible skin that requires no peeling. Fruits are generally 22-30 cm long, and 300-400 g in weight. Parthenocarpic cucumber lines have the potentiality to set large number of fruits without pollination, which can increase their productivity many times inside the polyhouse condition. The production technology of parthenocarpic cucumber has been developed and standardized for its cultivation under naturally ventilated greenhouse conditions. Three crops of

parthenocarpic cucumber can be grown over duration of 10-11 months under naturally ventilated green house conditions with high productivity and very high quality fruits.

The concept of polyhouse vegetable breeding programme was developed at Pantnagar during 2002 in cucumber. Some of the good genotypes were isolated and pure line and hybrid breeding programme were adopted for improvement of these genotypes. After three years of multilocational testing at Tarai, Mid hills and higher hills under polyhouse condition, two genotypes were identified for release, which are in Parthenocarpic Cucumber. These identified genotypes were released by Uttarakhand State Variety Release Committee during May 2011.

The distinguishable traits are as below:

A) Pant Parthenocarpic Cucumber -2

1. The first harvesting starts after 30 days of sowing.
2. Plant bears only female flowers (gynoecious), 551 in number per plant
3. The single fruit weight is 630 gm.
4. The average yield is 1755 q/ha.

B) Pant Parthenocarpic Cucumber -3

1. The first harvesting starts after 32 days of sowing.
2. Plant bears only female flowers (gynoecious), 465 in number per plant.
3. The single fruit weight is 415 gm.
4. The average yield is 1605 q/ha.
5. Plant produces seedless fruits (Parthenocarpic in nature)

Production technique in greenhouse cucumber

Cucumber is warm season crop and requires high temperature of 20-30^{0}C and plenty of sun light to produce good crop. The optimum soil temperature for cucumber production should be 15-18^{0}C because lower temperature delays plant growth and development of fruit especially in greenhouse cucumber. Prolonged temperature above 35^{0}C should also be avoided as fruit quality and production gets minimized.

Greenhouse cucumber is established in greenhouse as transplants. The cost of seed is high while germination percentage is near to 100%, so one seed/hill or bag is sufficient. The seeds of cucumber germinate rapidly within 3-4 days when the optimum temperature is available in greenhouse. During seedling or transplanting, the plant should never be stressed for nutrient and water. Plants are ready for transplanting at 3-4 true leaf stage. Greenhouse cucumber plants have very large leaves, grow vigorously and require large amount of sun light. In good sun light conditions or in warm weather 150-200 cm square space should be provided to plants in greenhouses but where light conditions are poor, more spacing is required for good growth of the plants. Exact spacing between row to row and plant to plant depends upon variety, soil fertility, light requirement, training and production system of crop.

Training and pruning is also needed for greenhouse cucumber. The basic principle of

training system is to uniformly maximize the leaf interception of sunlight throughout the greenhouse. Generally 2 types of training systems are used depending upon greenhouse facilities and the choice of the grower. First one is vertical cordon system, in which plants are trained vertically to an overhead wire. Once the plants reach the wire, they are topped and then pruned using an umbrella system. The second one is V cordon system. In this case, the plants are trained up the strings and grow an incline way from low center. The plant formulatess a V shape arrangement down to row.

Cucumbers are trained on plastic wires running horizontally. The base of string can be anchored loosely to the base of the stem. As the stem develops it can be fastened to the string with clips and only one stem is allowed to develop. Fruit buds should be removed from first five leaf nodes. Thereafter, fruits should be allowed to develop but all laterals and tendrils should be removed alongwith the old leaves from the old part of the stem.

Nutrients

Greenhouse seedless cucumbers have a high nutrient requirement and grow very rapidly when supplied with sufficient nutrients. As a result, growers must plant for an optimum nutrient programme making adjustments in the programme as the crop demands change. The greatest demand for nutrients is during the peak fruit production period. Nitrogen and potassium is required in greatest amounts; however, complete nutrition programmes including essential minor elements are also required. Designing a fertility programmme varies depending on the production system desired and extreme caution must be used when interpreting or comparing research or articles from one production system to another. Florida greenhouse producers are using soilless production systems. In these systems, a complete nutrient solution is used to supply nutrients needed to the crop. Soilless culture increases the grower's ability to control the growth of the plant, but it also requires management to achieve success. Soilless growers must supply their crop with six macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur), along with the other 7 micronutrients (iron, manganese, copper, zinc, molybdenum, boron, and chlorine). It is especially important in soilless system to test the source of water prior to developing a nutrients programme. The pH of the water is also critical and may need to be adjusted. The target pH of the nutrient solution supplied to the plants should be between 5.5 and 6.0. Either nitric, sulfuric, or phosphoric acid is recommended for pH control. If it is necessary to raise the pH, potassium hydroxide is usually used. If the source water is alkaline due to high carbonate concentrations, the pH should be adjusted before the fertilizer salts are added to prevent precipitation. Plant tissue testing can be a useful tool in addition to good soil testing or nutrient solution programme to monitor the fertility. Several research articles report a sudden temporary wilt of greenhouse cucumber plants when using NFT. Cucumber roots have greater oxygen requirement when compared with roots of tomatoes. Cucumbers develop a large root system in growing tubes and as a result may become stressed for oxygen. Due to this concern, measures are needed to be taken

to provide improved oxygen supply to the root zone. High solution temperatures also reduce the amount of dissolved oxygen in the solution. The growers must avoid high temperatures in the solution.

Fruit development

A fruit may develop at each node and more than one may begin to develop at some nodes. It is usually best to thin these multiple-fruit clusters to a single fruit; however, vigorous plants can sometimes have more than one cucumber at a node and any distorted fruit should be removed immediately. The greatest growth of the fruit occurs between day 6 and 14 after the bloom opens (anthesis). Maximum fruit length occurs at day 14 followed by diameter increase. The shape of the fruit is somewhat tapering at the stem end prior to day 10 after the bloom, however, the fruit becomes uniformly cylindrical by day 14. During the spring season, commercially acceptable fruit size is usually reached by the 11^{th} day after the bloom opens.

Harvesting

With good management each plant may produce about 6-7 kg fruit over a period of 3-4 month period. Cucumber fruit is harvested when it attains a size of 10-14 inches long. After harvesting fruits are stored at 10^0C with 70-80 % relative humidity.

This technology eliminates stresses due to biotic and abiotic factors and the use of pesticides can also be minimized. The technology is highly remunerative for the growers near periurban areas of the country who can access and target niche markets. The growers can also take full advantage of the offseason produce cucumber, which is not possible under outdoor cultivation.

Monitoring and Decontamination of Pesticide Residues in Farm Gate Vegetables

Anjana Srivastava
Department of Chemistry, G.B.P.U.A.&T., Pantnagar- 263 145 (UK)

Vegetables form an important component of human diet. They are however, infested by various insect pests like aphids, jasssids, diamond moths, caterpillars, etc. Among the vegetables, brinjal, cauliflower, tomato and okra etc. are some very common vegetables cultivated, throughout the country but all are badly affected by insect-pest and diseases. In India, farmers use about 6000 tonnes of active ingredients to control pests of vegetables and fruits . Vegetables consume 14% of the total pesticides used in India, in which, the share of different types of pesticides in Indian agriculture market shows that organophosphorus (50%) rank first, followed by pyrethroids (19%), organochlorines (18%), carbamates (4%) and biopesticides (1%). Pesticide application is a necessary step for coping with the pest related problems and therefore, it is not possible to meet the requirements of our ever growing population without pesticide application. Indiscriminate use of pesticides particularly at fruiting stage and non adoption of safe waiting period leads to accumulation of pesticide residues in consumable vegetables. Since most of the pesticides are toxic in nature, their continuous ingestion by man even in trace amounts, can result in their accumulation in body tissues with serious adverse effects on health. Hence it is important to assess the pesticide residues in vegetables so that they may be removed to the maximum extent possible.

Estimation of pesticide residues

The estimation of pesticide residues involve several steps like extraction of pesticide with a suitable solvent, concentration of the solvent, partitioning with some polar / nonpolar solvent, clean up and finally the analysis through HPLC, HPTLC or GC for quantitative estimation of the pesticides.

Since several pesticides are used on one type of vegetables, therefore a multiclass pesticide residue analysis method is more appropriate for quantitative determination of pesticide levels in vegetables. For example cypermethrin, imidacloprid and carbendazim are being used on okra, chlorpyrifos , imidacloprid and carbendazim on tomato etc. Chlorpyrifos and imidacloprid (insecticides) and carbendazim(fungicide) are a few such pesticides which are being invariably used on almost all the vegetables and so a method which can be used for estimating the pesticide mixture is more desirable than the one which will estimate only a single compound.

Solvents like acetone, acetonitrile, ethyl acetate, dichloromethane, methanol, hexane and propenol-2 are some common solvents which are used for extraction of pesticide residues. Similarly adsorbents like alumina, neutral silica gel G and charcoal are used for column cleanup. After going through the rigorous extraction and clean up processes the sample is subjected to GC, HPLC or HPTLC analysis for quantitative determinations of pesticides as these techniques

allow the estimation of even trace amounts of pesticides in any commodity. However, in these chromatographic analysis estimation of pesticide residues is done on comparison basis with that of technical standards.

Pesticides, being toxic in nature, are supposed to be thoroughly screened for their safety, using different animal models. For this purpose, studies on acute toxicity, chronic toxicity, allergenicity etc., are undertaken. These data are evaluated and the No-Observed-Adverse-Effect Level (NOAEL) is calculated from the chronic toxicity studies. In case of toxic pesticides, acute reference dose is also taken into consideration. This NOAEL and Acute Reference Dose are supposed to be taken as the starting information for prescribing the tolerance limits of pesticides in food commodities. NOAEL is usually referred to in terms of milligrams of that particular pesticide per kilogram of body weight.

From this NOAEL, the Acceptable Daily Intake (ADI) is calculated which is expressed in terms of mg/kg body weight and is an indication of the fact that if a human being consumes that amount of pesticide everyday, throughout his lifetime, it will not cause appreciable health risk. On the basis of this MRL is a dynamic concept which is determined and is also renewed from time to time. Maximum Residue Limit (MRL) is the maximum concentration of a pesticide residue resulting from the use of a pesticide according to Good Agricultural Practice (GAP). It is the limit that is legally permitted or recognized as acceptable in or on a food, agricultural commodity, or animal food. The concentration is expressed in milligrams of pesticide residue per kilogram of the commodity. Under the PFA Act, MRL or Tolerance Limits (TLs) are fixed considering MRLs recommended by Codex or based on supervised trials conducted in India as well as the dietary habits of our population.

Decontamination of pesticide residues from vegetables

The decontamination of pesticide residues from vegetables is an extremely important step to be followed in view of the extreme doses of pesticides which are being used on vegetables, especially the ones which are consumed raw. The different methods which can be employed for decontamination of pesticides are

Washing: Household washing procedures are normally carried out with running or standing water at moderate temperatures. Chlorine or ozone can also be passed into wash water to improve effectiveness of washing. The effects depend upon the physicochemical properties of pesticides such as water solubility, hydrolytic rate constant, volatility and octanol – water partition coefficient. Washing process leads to reduction of hydrophilic pesticide residues on the surface of the vegetables. The temperature of washing water also has an influence on the reduction of residue level from vegetables as hot washing leads to higher reduction in pesticide residues than cold water. Washing coupled with gentle rubbing under tap water dislodges pesticide residues significantly.

Peeling: The outer leaves of vegetables often contain residues of applied pesticide during crop growth. There are several examples depicting the presence of high pesticide residue

concentrations in the peel of the vegetables.. Therefore peeling or trimming removes about 50% of the pesticide residues from the vegetables.

Cooking: The process of cooking or boiling vegetables by heating at different temperatures reduces the pesticidal contamination of vegetables to the maximum level especially the organophosphorus pesticides. During this process the pesticides are translocated into the cooking water or degraded to other compounds reducing the level of original pesticide toxicity.

Dip treatment: The dipping of vegetables in mild chemical solutions like NaCl, dilute HCl, CH_3COOH, NaOH and $KMnO_4$ have been reported to reduce a high percentage of pyrethroid residues in vegetables.

The above decontamination methods, if applied, bring down the pesticide residue levels within the recommended MRL values in vegetables which are then considered to be safe for consumption.

Transfer of Protected Production Technology to Hill Farmers

M.P. Singh
Regional Research Station & KVK Lohaghat (Champawat), G.B.P.U&T. Pantnagar (UK)

Uttarakhand is primarily a mountainous state with about 10% of its total geographical area in the plains. The state is having about 64.8%area under forests. The share of net sown area is only 12%as against a national average of 43.37%.Out of the total 7, 66,730ha net sown area 2, 87,000ha is under horticultural crops. Agriculture is the main source of livelihood of majority of the population of hilly areas of Uttarakhand. More than 71.42 % farmers are marginal farmers, and having fragmented and scattered land holding less than 1 ha. Agriculture is largely traditional and rain fed and farmers practicing ragi/rice-wheat, soybean-wheat cropping system. Although, great developments has been taken place in field of agriculture during last few decades, farmers of hilly areas of Uttarakhand are still following traditional farming which are not very remunerative. Agriculture production is hardly sufficient to meet the domestic requirement for even a period of 4-5 months. Majority of the farmers particularly in rural areas fall below the poverty line. They do not have regular source of income to keep up their family. Therefore, there is great need of diversification to enhance the income of poor farmers. The horticulture viz. fruit crops, vegetable production and floriculture are one of the best ways of diversification in agriculture.

Uttarakhand is endowed with varied climatic conditions, which are suitable for the production of various vegetables during off season in different areas around the year. The major vegetables namely tomato, capsicum, cabbage, cauliflower, French bean, vegetable pea and potato are being grown by the farmers. Total area under vegetable cultivation are 606507 ha with productivity of 9.86 MT/ha. Which is very low as compare to Himachal Pradesh i.e. 17.5 MT/ha.

Table: 1 Area, production & productivity of major vegetable crops in Uttarakhand (2010-11)

S. No.	Name of corps	Area (ha)	Production (MT)	Productivity (q/ha)
1	Tomato	8783	97077	110.53
2	Capsicum	2319	12738	54.92
3	Cabbage	5609	70461	125.62
4	Cauliflower	2550	33966	133.20
5	French bean	5176	38112	73.63
6	Veg. Pea	11187	86937	77.71
7	Brinjal	2228	25870	116.11

Source: Directorate of Horticulture and food processing Uttarakhand 2010-1

Major factor for low production of vegetables

Unavailability of quality seeds/planting materials and agrichemicals in hilly areas of Uttarakhand are major constraints for production of vegetables. Drought, erratic behavior of rains, hail-storm, frost and heavy snow fall in high hills is major a biotic factors which are responsible for 10-60% losses in vegetables production.

In view of the lucrative returns from vegetables framers with limited land for cultivation are

forced to follow monoculture, which provides congenial condition to survival of various pathogens/insects from one season to another. Beside this, other causes viz. use of un-decomposed FYM, traditional methods of nursery raising are responsible for higher disease incidence/insect infestation and causing considerable losses (5 to 35%) by reducing yield and quality of produce. Vegetable crops are also badly devastated by wild animals like barking deer, pigs, monkeys, rabbits and porcupine.

Technological Interventions: The production of horticultural crops in hills of Uttarakhand depends on three major factors i.e. natural climatic conditions, infrastructure and institutions, and incentive for producers. Therefore, there is a need to adopt new technological interventions supplemented with institutional support for growth of the sector and remunerative returns to the producers.

Rain water harvesting technology:

Rainfall in Uttarakhand is highly irregular and most of it is concentrated during few months of the year and maximum amount flows away and resulting in poor recharge of ground water. Rainwater harvesting is a method to capture and store rainwater for various uses. There are various methods of rain harvesting i.e. harvesting of watershed management, harvesting of rainwater on rooftops and open spaces and stored in poly tanks, small ponds, harvesting through lakes (Eris) and harvesting through recharge wells. Rainwater harvesting techniques are very useful to sure irrigation particularly in hills of Uttarakhand for maximum production of vegetables.

Advantages of Rain water harvesting technology:

- It conserves soil moisture, increases water availability, checks the declining ground water table and prevent soil erosion and flooding.
- It is a low cost and eco-friendly technique for preserving every drop of water.

Drip irrigation system:

Drip irrigation system is one of the most efficient methods of watering of plants in polyhouses and raised beds poly tunnels for growing off-season vegetables/flowers. In drip irrigation, tubes that have emitters run alongside the plants receiving irrigation. The water leaves the tubing through the emitters by slowly dripping into the soil at the root zone. This method of irrigation minimizes leaf, stem and fruit contact with water resulting in reduced plant diseases. It reduces weed growth by keeping the area between the plants dry and irrigation through Drip method.

Advantages of D**rip irrigation system:**

- It is low labour intensive, highly efficient system of Irrigation and saving 36- 79% Irrigation water.
- Its reduced runoff, evaporation this system is ideal for the raised beds covering with poly mulching, in polyhouses and poly rate.
- Minimize infestation of pest and diseases, weeds problems

Plastic mulching

Mulching is a practice of covering of soil around plants. Use of black polyethylene sheet (50-100 *micron*) as mulching makes growing condition more favorable by conserving soil moisture for longer time, maintaining soil temperature during winter season, preventing weeds and allowing soil micro flora to be favorably active.

Advantages of vegetable production in poly mulching:

- It conserves soil moisture by preventing water evaporation form it.
- It prevents germination of annual weeds because of its opaqueness.
- Plastic mulches maintain warm temperature during night which facilitates an early establishment of seedlings by strong root system or germination of seeds.
- Minimizes soil water erosion.
- Plastic mulches serve for longer period. They can be used for more than one season.
- Provides cleaner crop produce.
- More income through early, higher and quality yields.

Low tunnel poly house techniques:

Transparent plastic films or nets are stretched over low (1.0 m or so) hoops made of steel rod, bamboo, rose twigs or any other locally available suitable material to cover rows of plants in the fields or nursery bed. These techniques providing protection against unfavorable environment like low temperature in winter, frost, hail storm, heavy rains during rainy season, cold wave and insect-pests.

Advantages of low tunnel poly house techniques:

- Seedlings are ready to transplant 15-20 days earlier than open condition.
- 40-50% more healthy seedling production as compared to traditional methods.

Poly house / green house for high value vegetable cultivation:

Poly house / Green house is framed structure having 200 micron (800 gauges) UV stabilized transparent or translucent low density polyethylene or other claddings which create green house effect making micro climate favorable for the plant growth and its development. This structure is large enough for a person to work inside. The structure can be made in different shape and size using locally available materials like steel, aluminum, bamboo or other combinations for its frame. Insect proof net and shading materials are used to keep insect at bay and to lower temperature in summer.

Table 2: recommended varieties for poly house condition in Uttarakhand

Sl. No.	Name of crop	Verities
1.	Tomato	Rakshita, Naveen 2000+, Avinash, snehlata, Pant poly house tomato-2, Heem sohna, PPBT-Y, PPBY-9
2.	Cucumber	Isatis, Kiyan, Pant parthenocarpic cucumber-2, PCUC-2
3.	Capsicum	Tanvi, Bharat, Natasha, Indira, Swarna, Ganga

Advantages of vegetable production in poly houses in hills:

- Raising of vegetable nursery earlier and advancing the availability is also possible by use of polyhouse.
- Cultivation of vegetables /cut flowers during winter months at subzero temperature when it is not possible to grow them in open field conditions.
- Polyhouse cultivation is ideally suited for hill farmers having small and scattered land holdings.
- Productivity per unit area and the time can be increased by adopting suitable crop sequences.
- Polyhouse conserves the moisture. Hence frequencies of watering to plants get reduced.
- Farmers can advance/delayed and segregated production of vegetables as per market demands.
- The yield may be 5-6 times higher than open cultivation depending upon the type of poly house and type of crop, environmental control facilities.
- Cultivation of vegetables under poly house by farmers provide safeguard against adverse weather and enhance life spawn of the crops.
- Better quality produce than open cultivation.
- Insect-pest and weed managements are easier in polyhouse than open field.

Table 3: Management of Insect-pest/diseases in protected cultivation

S. No	Major Insect-pest	Crop affected	Symptoms	Management
1	Cutworm *(Agrotis spp.)*	Nursery of tomato & capsicum	Larvae cut young plants at ground level	Spray the crops with chlorpyriphos20 Ec (2ml/l)
2	Aphid	Tomato, capsicum, cucumber, cole crops	Nymph & adult suck the sap from the plants. They cause stunted growth with curled, twisted leaves & deformed fruits. They also secrete honey dew which allows the growth of black sooty moulds.	Neem oil (5ml/l), Imidaclorpid 17.8SL (0.4ml/l), Quinalphos 25 Ec (2ml/l)
3	White fly *(Bemisia tabaci)*	Capsicum, chillies, cabbage, cucumber	Nymphs and adults suck the sap from leave and vitality of the plant is lower through the loss of cell sap. They also secrete honey dew which attracts fungus (sooty mould in capsicum). The insect transmit various virus diseases in tomato, capsicum & cucurbits	Imidaclorpid 17.8SL (0.4ml/l), Quinalphos 25 Ec (2ml/l)
4	Cabbage butterfly *(Pieris brassicae)*	Cole crops	The 1st instar larvae just scrape the leaf surface, whereas the subsequent instars eat up the leaves from margin inwards, leaving intact the main veins	Quinalphos 25 Ec (2ml/l)

5	Leaf miner	Tomato, capsicum, cucumber	Larve mine into the tender leaves in zig-zag manner and scrape chlorophyll. Photosynthesis is adversely affected, vitality is reduced and there is an appreciable reduction in yield.	Methyldemeton 25 Ec (1ml/l)
6	Thrips	capsicum, cucumber, cole crops	Affected leaves of plants become curled, wrinkled & gradually dry up. Feeding cause flower or leaf buds to abort or emerging leaves to become distorted.	Neem oil (5ml/l), Imidaclorpid 17.8SL (0.4ml/l), Quinalphos 25 Ec (2ml/l)
7	Mits	Tomato, capsicum, *cucumber	Small brown or yellow dotes on the leaves of plant are most easily observed sign of a mite infestation. Severely infested plant leaves become discolored, producing an unthrifty gray or bronze look to the plant.	Dicofol (2.5ml/l), penconazole (0.4ml/l), Neem oil (5ml/l), Wettable sulphur (2g/l)
8	Powdery mildew	Capsicum, cucumber	Leaves, buds and stem are cover with white powdery coating. Affect leaves curl upwards	Wettable sulphur (2g/l), Warbendazim (0.5g/l), Hexaconazole (0.5ml/l)
9	Damping off/Post damping off	Tomato, capsicum	Failure of seedling emergence from the soil results in patchy appearance of seedlings stand in the nursery in early stages of growth. (Pre-emergence) toppling over of infected seedlings at any time after their emergence from the soil resulting in mortality of the seedlings.	Soil solarization of nursery bed, Metalaxyl (1gm/l), Trichoderma (10gm/m^2), Carvendazim(1gm/l)+ Capton (2gm/l)
10	Root knot nematodes	Tomato, capsicum	Root nodulation/galls on the roots.	Drenching with Carbofuran (6g/m^2)
11	Fusarium wilt	Tomato, capsicum	Yellowing and drooping of plants, wilting of leaves, stunting and browning of vascular system.	Metalaxyl (1gm/l), Trichoderma (10gm/m^2)
12	Late blight	Tomato, capsicum	The disease is characterized by the appearance of brown dead areas on leaves, which initially appear as faded green patches and later turn into brownish black lesions spreading rapidly during wet weather. Within 3-4 days of wet weather whole plant may get blighted.	Ridomil (2.5ml/l), Mancozeb (2.5ml/l)
13	Buck eye rot	Tomato	Spots on tomato fruit mark with pale brown, concentric rings resembling slightly the marking on a buck eye.	Ridomil (2.5ml/l), Mancozeb (2.5ml/l), Copper oxy-cloride (3g/l)
14	Septoria leaf spot	Tomato	The spots appear as small, water soaked, more or less circular spots in outline and show definite brown colored margins with grey centers.	Mancozeb (2.5ml/l), Copper oxy-cloride (3g/l)

15	Bacterial wilt	Tomato, capsicum	Sudden drooping of leaves, without yellowing resulted in wilting of the plants.	*Pseudomonas fluorescens* (10g/m^2), Bleching power (300g/200m^2), Streptocycline (0.1g/l) + Copper oxy-chloride (3g/l)
16	Blossom End Rot (Calcium deficiency)	Tomato	Lesions appears at blossom end of the fruit. The affected portions of the fruit become sunken, leathery and dark colored.	Calcium Carbonate (5g/l)

Major activities conducted by KVKs for Dissemination of Protected cultivation Technology :

- Conducted training of farmers, personnel of various line departments on protected cultivation.
- Organized FLDs/OFTs on farmers' field to demonstrate new technology.
- Organized exposer visits of farmers' at KVK to demonstrate new technology on protected cultivation.
- Motivations /Advisement of farmers towards protected cultivation.
- Diagnostic visits of farmers' field for identification s and suggestions for pest and disease management.
- Published popular articles, extension bulletins, folders on protected cultivation.
- Organized kisan mela, gosthi, farmer's scientist interaction and workshop of farmers to create awareness among farmers towards protected cultivation.
- Radio/TV talks on protected cultivation
- Print media (Daily News Paper) and electronic media (Mobile Services, and voice sms) are used for quick information and message delivered to farmers.
- Provided black polyethylene sheet, poly tunnels, quality planting materials and agro-chemicals to farmers as new critical inputs.

Table 4: Functional linkage with different organization for dissemination of technology

Name of the programme	Institution involved	Kind of linkages
Dissemination of poly tunnel technology for quality nursery raising and production of winter vegetables for the weaker section farmers of the he district Champawat.	VPKAS (ICAR), Almora U.K. (HMNEH MM-1)	Project funded, knowledge sharing ,critical inputs
Large Scale Demonstration of vegetable. production technology in Uttrakhand	VPKAS (ICAR), Almora U.K. (HMNEH MM-1)	Project funded, knowledge sharing ,critical inputs
Large Scale Demonstration IPM technology in Uttrakhand through KVK Network Mode	VPKAS (ICAR), Almora U.K. (HMNEH MM-1)	Project funded, knowledge sharing ,critical inputs

Protected cultivation of high value vegetables and cut flowers –A value chain approach	National Agricultural Innovative Project ,ICAR New Delhi	Project funded, critical inputs, evaluation and standardization of protected cultivation of high value vegetables and flowers in hilly areas of Uttrakhand
Popularization of fish-poultry-vegetable integrated farming technology for socio-economic up liftment of fish farmers of kumaun region of Uttrakhand	Department of Bio-technology, New Delhi	Project funded, critical inputs Trainings,
Formation of kisan club & training programme	NABARD	Cooperation & participation in training and meetings
Technology refinement & training programme on Protected cultivation	GBPUA&T Pantnagar	Knowledge sharing & participation in meetings
Trainings ,meetings and Gosthi	Department of Horticulture &Food Processing Champawat	Coordination in planning of trainings, implementation and execution of programmes
Trainings/PMRC of project	NIDHI, SAMANDH (NGO's of district)	Technical assistance & advisement, exposure visit of farmers and demonstrations

Table 5: Impact/Adoption of Protected cultivation Technology

Technologies	Activities	Accomplishments	Impact
1. Rain water harvesting technology for veg. production	Trainings, FLDs, Field visit, meetings were organized for dissemination of technology	Increased irrigated area Life saving irrigation during dry spell. Promotion of round year vegetable production.	• 50-60 % increased in yield against rain fed cultivation of off season veg. • 215 farmers are successfully using this technology for veg. production
2. Use of black poly mulch in off season veg.	• Demonstrations on poly mulching technologies for production of veg. at farmers field • Skill development through trainings and field visits	• Minimized 90-95% weed incidence • Retain soil moisture for longer time • Increased 30-40 % production as compared to un protected field	125 farmers have adopted poly mulching technology for veg. production and harvesting 30-40% greater production as compared to traditional method
3. Use of poly tunnel technology for vegetable seedling production	• Demonstrations on veg. nursery growing under poly tunnel at farmers' field • Skill development through trainings and field visits	•40-50% higher seedlings are produced as compared to traditional method •Seedling are ready to transplant 15-20 days earlier than traditional method •80-90% protection against biotic and a-biotic factor	250 farmers have adopted poly tunnel technology for raising off season veg. seedlings

4. High value off season vegetable production in poly house	• Demonstrations on poly house technology for production of veg. at farmers field • Skill development through trainings and field visits	•Crops are protected against a-biotic & biotic factor •50-70% higher production •20-35 day early fruiting •2-3 months longer fruiting period	Presently 496 farmers are producing off season veg. like capsicum, tomato & cole crops in poly houses & earning net income of Rs 8000-12000/40 sq. m. area/ year
5. Value addition of Horticultural crops	Training on rural women and rural youth	•Rural women are trained and prepared various products like squash, pickles of available surplus vegetables and fruits for their own consumption and marketing also.	•Better utilization of fruits and vegetables. •250 trained women preparing various preserved fruits and veg. products for their family use.

REFERENCES

- Atwal A.S. 1991. Agricultural Pests of India and South-East Asia. *Kalyani Publishers*. 528pp.
- Bisht B.S. 2012 Prospects and Scenario of Protected Cultivation of Horticulture Crops in Uttarakhand. *National Seminar on Protected Cultivation of Vegetables and Flowers- A Value Chain Approach 11-12th January, 2012. Department of vegetable Science, College of Agriculture, G.B.P.U.A &T. Pantnagar (UK) India.* 1-8pp.
- Gupta, S.K & A. Honda. 2005. Important diseases of vegetable crops. *Department of Mycology and Plant Pathology Dr. Y.S. Parmar University of Horticulture and Forestry Nauni -173 230, solan, H.P.* 82 pp.
- Quinquennial Progress Report 2006-2010 *of KVK Lohaghat Champawat.* 36pp.
- Singh A.K. 2007. Parvatiya Anchal Ma poly House kheti. *Published by KVK Lohaghat Champawat. 822pp*
- Singh Brahma & Singh Narendra. 2012. High Altitude protected Vegetable Production. *National Seminar on Protected Cultivation of Vegetables and Flowers- A Value Chain Approach 11-12th January, 2012. Department of vegetable Science, College of Agriculture, G.B.P.U.A &T. Pantnagar (UK) India.* 21-26pp.
- Singh M.P. 2012. Progress report of Large scale Demonstration of IPM Technology through KVK Network Mode. KVK Lohaghat Champawat. 12pp.
- Sabir N, S Raj & S.H. Naved. 2012. IPM in Green House Vegetables. *National Seminar on Protected Cultivation of Vegetables and Flowers- A Value Chain Approach 11-12th January, 2012. Department of vegetable Science, College of Agriculture, G.B.P.U.A &T. Pantnagar (UK) India*. 61-70pp.

Diseases of Vegetable Crops under Protected Cultivation

R.P. Singh, Mamta Mathpal and Supriya Gupta
Department of Plant Pathology, G.B.P.U.A&T., Pantnagar- 263 145 (UK)

India is the second largest producer of fruits and vegetables in the world. Area and production of vegetables in the world amounts to 7980.7 thousand hectares and 129076.8 thousand tonnes respectively. Out of it India's contribution in terms of area, production and productivity is 634.4 thousand hectare, 12433.2 thousand tonnes and 19.6 t/ha respectively. Due to increasing demand and to maintain year round supply of vegetables, protected cultivation thus provides a better alternative with huge future prospects.

Polyhouse is a framed structure having 200 micron UV stabilized transparent or translucent low density poly ethylene or other claddings which create green house effect making microclimate favourable for plant growth and development. The structure is large enough for person to work inside, can be made in different shapes and sizes using locally available materials like steel, alluminium, brick or their combination for its frame. Insect poof net and shading materials are used to keep insects at bay and to lower temperatures in summer. Though greenhouse technology is more than 200 years old, but in India, the technology is still in its infancy stage. The area under green house cultivation is 2000 hactares including 500 ha net house, shed house and 1500 ha green house, which is mainly in Maharashtra, Uttarakhand, Karnataka, Jammu & Kashmir. There appears ample scope for increasing area under low cost polyhouse in many folds in peri urban areas for production of high value vegetables during off season for taking advantage of high price of available market in nearby cities. Crops like tomato, cucumber , capsicum, etc is being grown on large scale under polyhouse condition.

Fungal diseases

Fungal diseases constitute one of the biggest group of foliar pathogens causing immense damage under protected environment. It was found that the incidence and severity of diseases vary considerably under protected environment when compared to open field. As observed in tomato, *Phytophthora infestans*, *Pseudocercospora fuligena* and *Fulvia fulva* causing late blight, black leaf mold and leaf mold respectively were observed to be of higher significance under polyhouse condition. Further, the notion of early and late blight was found to be obscure under polyhouse condition. Since it was observed that late blight appears early in the crop season whereas early blight appears late during crop season. This may be attributed to the fact that temperature and humidity are nearly balanced inside protected structure, even when outside field temperature is comparatively low and so on. *Alternaria alternata* is found to be a major disease affecting fruits. Capsicum on the other hand is found to be infected primarily by *Colletotricum capsici, Cercospora capsici, Pythium, Fusarium* and *Phytophthora spp., Stemphylium solani* and *Stemphylium lycopersici, Sclerotium rolfsii, Verticillum alboatrum and V. dahlie ,Phytophthora capsici, Leveillula taurica* and *Botrytis cineria* causing anthracnose, leaf spot, damping off, grey

leaf spot, stem rot, Phytophthora blight, powdery mildew and grey mold respectively. Cucumber also attracts a considerable quantum of fungal pathogens. Out of which downy mildew (*Pseudopernospora cubenses*), Powdery mildew (*Ersiphe cichoracirum and Sphacelotheca fuligena*), Alternaria leaf spot (*Alternaria cucumerina*),Anthracnose (*Colletotricum lagenarium*) and Damping off (*Pythium spp*) are important. Survival of pathogen is also enhanced inside polyhouse due to availability of host because of longer growing season.

Bacterial diseases

Bacterial diseases are less frequent but under high moisture and poor irrigated condition may cause huge damage. *Erwinia carotovora ssp. carotovora* (Bacterial soft rot) , *Xanthomonas campestris pv. vesicatoria* (Bacterial spot), *Ralstonia solanacearum* (Bacterial wilt). *Pseudomonas syringae* pv. *lachrymans* (Angular leaf spot), *Erwinia tracheiphila* and *Ralstonia solanacearum* (Bacterial wilt) are pronounced to name some.

Viral diseases

Tomato, cumcumber and capsicum are very sensitive to virus diseases under protected environment. It often spreads in the plantation by insect vectors such as whitefly, thrips and aphids. The damage caused by the virus is usually much greater than the mechanical injury caused by the insect vector. Plant tissue damaged by a viral disease does not die immediately. The most important symptom of viral infections is the light (white or yellow) colour of the leaves, or a mosaic pattern of light and darker shades of green on the leaves. In many cases, viral disease leads to dwarfed growth, rosette formation or other strange stem, fruit and leaf deformations. The symptoms of viral infections are often not found everywhere in a cultivated field but rather in patches and also sometimes without symptoms. Viruses prevalent among greenhouse crops include Tobacco mosaic virus or tomato mosaic virus (TMV or ToMV), Cucumber mosaic virus (CMV), Tobacco etch virus (TEV), Potato virus-Y (PVY), Potato leafroll virus (PLRV), Tomato spotted wilt virus (TSWV), Alfa- Alfa mosaic virus, Pepper veinal mottle virus (PVMV), Pepper mild mottle virus(PMMY), Chilli veinal mottle virus (CVMV Or Chivmv), Tomato yellow leaf curl virus (TYLCV), Tomato Big-Bud mycoplasma (TBB)

Management strategy

Proper field sanitation is the one of most important management strategy, since once the build up of innoculum occurs inside polyhouse it is very difficult to manage it. So prevention is always better than cure. Use disease-resistant varieties. Reduced incidence of leaf wetness by staking plants providing ample spacing between plants to allow for good air movement, and avoiding overhead irrigation. Judicious use of chemicals with least toxicity recommended specially for polyhouse cultivation shoud be done. Chemicals like chlorothalonil, cymoxanil and azoxstrobulin are prohibited in polyhouse grown tomato and thus should be avoided. As for viruses scout fields for the first occurrence of virus disease. Where feasible, pull up and destroy infected plants, but only after spraying them thoroughly with an insecticide to kill any insects they may be harboring. Use reflective mulches to repel insects, thereby reducing the rate of spread of insect-borne viruses. Monitor vector population early in the season and apply insecticide treatments when needed. Minimize plant handling to reduce the amount of virus spread mechanically.

Characterization of Plant Pathogens through PCR

J. Kumar and Smita Puri
Department of Plant Pathology, G.B.P.U.A&T., Pantnagar- 263 145 (UK)

The Polymerase Chain Reaction (PCR) is a powerful, extremely sensitive technique employed in the field of Molecular biology, Agriculture diagnostics, Forensic analysis and population genetics. It is based on the enzymatic amplification of DNA fragments that is flanked by oligonucleotide primer hybridizing to opposite strands of the target sequence. The PCR involves three basis steps which constitute a single cycle:

i. Denaturation of the target DNA at 92-94°C
ii. Annealing of the primers to the template DNA.
iii. Primer extension by addition of nucleotides to the 3' end of the primers by the enzyme DNA polymerase.

As the number of PCR cycle increases, the amount of target DNA synthesized increases exponentially. Availability of thermostable DNA polymerase-Taq (from the bacteria *Thermus aquaticus*) has facilitated automation of the PCR.

Significance of PCR- The central scientific fact that makes PCR so useful is that- The genetic material of each living organism-plant or animal, bacterium or virus-possesses sequences of its nucleotide building blocks (usually DNA, sometimes RNA) that are uniquely and specifically present only in its own species. These unique variations make it possible to trace genetic material back to its origin, identifying with precision at least what species of organism it came from, and often which particular member of that species.

Such an investigation requires, however, that enough of the DNA under study is available for analysis-which is where PCR comes in. PCR exploits the remarkable natural function of the enzymes known as polymerases. These enzymes are present in all living things, and their job is to copy genetic material (and also proofread and correct the copies). Sometimes referred to as "molecular photocopying," PCR can characterize, analyze, and synthesize any specific piece of DNA or RNA. It works even on extremely complicated mixtures, seeking out, identifying, and duplicating a particular bit of genetic material from blood, hair, or tissue specimens, from microbes, animals, or plants, some of them many thousands-or possibly even millions-of years old.

PCR is invented by Kary Mullis and this invention brought him a number of scientific awards, among them most important were the Japan Prize and the Nobel, both awarded to him in 1993.

Constituents of PCR reaction

Primer- The most essential requirement of PCR is the availability of short oligonucleotides called primers having sequence complementary to either ends of the target DNA segment. **Primers** are short strand of nucleic acid serves as starting point of DNA synthesis.

Template DNA- DNA segment to be synthesized in large amount. Genomic DNA or RNA is used

as a template. CTAB method is used for isolation of genomic DNA from plant pathogens. Also liquid Nitrogen is used for grinding the mycelial mats, for effective disruption of the cell wall and cell membrane. Template DNA should be pure i.e not having any contamination of RNA and protein.

Ribonuclease enzyme is used (as per the protocol) for removal of RNA contamination from the genomic DNA of target plant pathogen. Quantification of the purified genomic DNA was done by checking the UV absorbance at 260 nm with the help of U.V. spectrophotometer. O.D. was also taken at 280 nm to calculate the ratio OD260/OD280. The ratio gives the amount of RNA (or) protein in the preparation. A value of 1.8 is optimum for best DNA preparation.

Taq DNA Polymerase- *Thermus aquaticus* DNA polymerase (Taq DNA polymerase) is a thermostable enzyme that replicated DNA at 72-74°C and remains functional even after incubation at 95^0C. The enzyme has 5'-3' polymerase activity and 3'-5' exonuclease activity.

DNTP's- The deoxynucleotidetriphosphates are dATP, dGTP, dCTP, dTTP (used as 10 mM each).

Assay Buffer (10X)- 10 X assay buffer for Taq polymerase enzyme. Assay buffer contains 10 mM Tris-HCl (pH 9.0), 15 mM MgCl2, 50 mM KCl and 0.01% gelatin.

Standardization of the PCR Conditions

There are number of variables in a PCR which have to be optimized to give target amplification. These parameters are:

- Denaturation temperature and denaturation time
- Annealing temperature and annealing time.
- Amounts of template and primer to be taken
- Concentration of $MgCl_2$ in the assay buffer
- The number of Cycles to be proceeded.

Preparation of PCR mixture: A master mix containing all the above mentioned components and no template DNA should be prepared in laminar airflow under sterile conditions for total no. of PCR tubes to be used. This will reduce the pipetting errors. Then distribute the master mix in each tube (24 µl each) and finally add 1 µl of different DNA template in each tube. Gently mix and centrifuge the mixture for 10 sec. Annealing temperature should be standardized using T-gradient programme.

Analysis of the Amplification (PCR) Products: Analysis of the amplicons will be done by Agarose Gel Electrophoresis in a submerged gel electrophoresis unit (for fractionating RAPD markers on agarose gel). Prepare Agarose gel (2.0%) by dissolving appropriate amount of agarose in 0.5X TBE buffer. For each well, mix DNA loading dye and DNA samples in 1:6 ratio and load with a micropipette. Start Electrophoresis at 80V for 3.5 hrs in 1.0X TAE electrophoresis buffer. Stain the gel in ethidium bromide solution. After destaining in deionized water, view the gel image in U.V. transilluminator and store in gel documentation system.

Data Analysis: score all the gels twice manually and independently. Indicate band presence by 1 and its absence by 0. Score all unique bands and include in the analysis. Presence or absence of unique and shared, polymorphic band should be used to generate similarity coefficients. The similarity coefficients then used to construct a dendogram manually by UPGMA (unweighted pair-group method with arithmetical averages).

Application of PCR in Plant Pathology - PCR technology has become an essential research and diagnostic tool for improving knowledge regarding identification, characterization, detection and diagnosis of plant pathogens. PCR technology allows scientists to take a specimen of genetic material, even from just one cell, copy its genetic sequence over and over, and generate a test sample sufficient to detect the presence or absence of a specific virus, bacterium or any particular sequence of genetic material. Therefore, it is hard to exaggerate the impact of the polymerase chain reaction. PCR, the quick, easy method for generating unlimited copies of any fragment of DNA, is one of those scientific developments that actually deserve timeworn superlatives like "revolutionary" and "breakthrough."

Diagnosis and characterization of the pathogen- PCR utilises specific oligonucleotide primers, which are designed based on nucleic acid sequences that are diagnostic for the pathogen. These may be sequences identified by genomic sequencing or techniques such as DNA fingerprinting of pathogens. To improve the sensitivity of these techniques, it is sometimes an advantage to use nested PCR methods, in which the products from the initial PCR amplification are diluted and re-amplified with a second set of primers internal to the original primer set in the pathogen sequence. These conventional PCR-based techniques have proved to be useful for diagnosis of fungal, bacterial and phytoplasma-associated diseases with a number of good taxon-specific primers developed for example from the rRNA subunit genes. Because of the sequence variation between these regions in different isolates, it has sometimes been possible to identify restriction endonucleases that give different restriction patterns upon digestion of the PCR products depending upon the isolate.

Primers have also been developed based on more specific sequences such as the *argk-tox* gene of *P. syringae* pv. *phaseolicola* which encodes a gene involved in phaseolotoxin biosynthesis and can be used to identify bacteria that possess this trait, or the *aflR* gene of *Aspergillus flavus* which regulates aflatoxin production in these fungi. In addition, PCR-based techniques have proved useful for identifying the vectors for insect-transmitted diseases. For example, DNA extracted from leafhoppers that are potential vectors for phytoplasma diseases can be PCR amplified using phytoplasma-specific primers to identify which species are the true vectors.

Single-strand RNA viruses can be detected by modifying the PCR to include a reverse transcriptase step (RT-PCR). In this, the reverse transcriptase uses a viral specific primer to make a cDNA copy of the viral RNA which is then amplified using Taq polymerase through conventional PCR. RT-PCR has the potential for use in diagnostics of bacterial and fungal pathogens. Through

identification of particular genes that are expressed during pathogen growth, or at specific stages of development, it may be possible to use RT-PCR to identify the developmental stage of the pathogen in infected material. It has also been possible to produce 'multiplex' PCR kits capable of detecting more than one pathogen present in a particular plant or soil sample. Kits are commercially available to unravel the cereal stem-based complex of fungi comprising *Tapesia yallundae* and *T. acuformis* (eyespot fungi), *Fusarium culmorum, F. avenaceum, F. graminearum* and *F. poae* (ear blights), and *Microdochium nivale* (snowmould of cereals).

REFERENCES

- Dickinson. M. 2005. Molecular Plant Pathology. BIOS Scientific Publishers, Taylor & Francis Group. London and New York.
- Schaad, N. W. and Frederick, R. D. 2002. Real-time PCR and its application for rapid plant disease diagnostics. Can. J. Plant Pathol. 24: 250–258.
- Gelsomino, G., Faedda, R., Rizza, C., Petrone, G. and Cacciola, S.O. 2011. New platforms for the diagnosis and identification of fungal and bacterial pathogens. In: Science against microbial pathogens: communicating current research and technological advances .(E_d_.) A. Méndez Vilas. 622-630.

Use of Biolog for Identification of Bacterial Plant Pathogens

R.P. Singh and Smita Puri
Department of Plant Pathology, G.B.P.U.A&T., Pantnagar- 263 145 (UK)

In recent years, popular methods for studying plant pathogens community structure were based on the analysis of phospholipid fatty acids (PLFA) or denaturing/temperature gradient gel electrophoresis (DGGE/TGGE) etc. The above-mentioned methods are based on molecular assays. Measurements of physiological activity of microorganisms represent another approach, allowing the study of different characteristics of microbial communities. The Biolog technique is one of the methods which rely on measurements of utilizing different carbon substrates by microorganisms. Measurements of substrate use enable qualifying microbial metabolic capabilities and hence functional diversity of a microbial community.

The Principle of the Biolog Method - The Biolog plate's method was first used to compare metabolic activity of heterotrophic microbial communities from different habitats such as water, soil and wheat rhizosphere. The technique is based on a redox system. Various types of plates are used, but Biolog GN plates for gram-negative bacteria are the most popular ones. Biolog Microbial Identification System is based on metabolic phenotypes. Biolog plates are plastic microtiter plates containing 95 different carbon substrates in wells, and no substrate in one well which is used as control. Among the 95 substrates one can distinguish a few groups of chemical compounds, for example, carbohydrates, amino acids, carboxylic acids, amines, amides and polymers. Biolog is based on the theory that a species of bacteria develops a unique metabolic finger-print on a set of carbon sources and biochemicals. The cultured bacteria are tested for utilization of different carbon sources and biochemicals, which are pre-filled and dried into a 96 well test plate. Additionally, each well contains a colourless Tetrazolium redox dye, used to colorimetrically indicate utilization of the substrates. Cells utilizing nutrient, respire and release energy which reduces proprietary Tetrazolium dye to form a distinct purple colour. Biolog data collection software is used to record the unique metabolic profile into the computer which can be compared with thousands of profiles (corresponding to thousands of species) stored in the Biolog databases. If the profile is matched, computer displays the identified species.

Biolog has designed proprietary microplates for identification of a wide range of microbes up to species level, such as Gen III plate (for gram negative and gram positive aerobic bacteria), AN plate (for anaerobic bacteria), YT plate (for yeast) and FF plate (for filamentous fungi). Nearly 2550 species are covered by Biolog for identification.

Application- It has been used for clean room analysis of microbial identification prevalent in environment, industrial quality control in analysis of food and/or agricultural products, plant disease diagnosis, veterinary, analysis of clinical samples including dangerous pathogens of human, animal and plant origin, education and research involving general and applied microbiology.

Different types of Biolog plates- The Biolog GNplates have been designed for identification of

gram negative bacteria and contain substrates appropriate for this group of microorganisms. Analogically, the GP plates are adapted for identification of gram positive bacteria. Two types of Biolog plates are available i.e. GEN II and GEN III. Microbial identification for GEN II MicroPlates involves five basic steps (identification process for AN, YT, or FF) while GEN III plates involves in four basic steps. These steps apply to all identifications. A small number of species have peculiarities that may require an extra step or special handling techniques.

The Microbial Identification Process for GEN II Micro Plates

Step 1: Isolation of a pure culture - As a first step to accurate microbe identification, streak agar plates using correct techniques to generate well isolated colonies. Always use Biolog-recommended culture media and growth conditions.

Step 2: Gram staining and determining test protocol- For bacteria, proper Gram stain technique and interpretation are the important second step in the ID process identification; use the wet prep test as necessary to differentiate yeasts from filamentous fungi.

Step 3: Prepare inoculum at specified cell density- Determine cell density using Colorimeter. Cell density describes oxygen concentration a key parameter to control when testing microorganisms in Micro Plates. Additionally, Biolog has carefully optimized the required inoculating fluids and standards.

Step 4: Inoculate and incubate MicroPlate- Pipette the specified amount of cell suspension into the Micro Plate, put the lid on, and incubate under the same conditions of temperature and atmosphere used to culture the microorganism. Biolog Micro Plates do not need oil overlays or color-developing chemicals.

Step 5: Read MicroPlate and determine ID- After an appropriate incubation time, read Micro Plates either by eye or using the Micro Station Reader. In either case, the pattern formed in the wells is entered into the software, which searches the database and provides identification in seconds.

Data is fed into a software enabled computer which performs analysis and reports the species of the isolated micro-organism.

- A large sized database is comprised of ~2550 species of which ~700 are of clinical importance.
- Gen II Microplate can be used to identify 1350 species of **aerobic bacteria**.
- AN Microplate can be used to identify 361 species of **anaerobic bacteria**.
- YT Microplate can be used to identify 267 species of **yeast**.
- FF Microplate can be used to identify 619 species of **filamentous fungi** (619 species).
- GN2 Microplate can be used to identify species of **gram negative bacteria**.
- GP2 Microplate can be used to identify species of **gram positive bacteria**.

Technology can be used in manual, semi-automatically or fully automatically as per the researcher's variable needs and budget.

Gen III Microstation System (Most preferred system)- GEN III Microstation is a semi-automated microbial identification system. It is Plate reader which is linked to a computer configured with software related to data collection and microbial identification software. It is capable of reading all types of Biolog Microplates. A microplate loaded with suspension of a test organism is incubated in a user-provided incubator and read using Microstation. The metabolic finger print is read and sent to the computer for recording and eventual comparative studies with profiles already stored in Biolog databases. Computer reports the species/genus when the metabolic finger print is matched with those present in Biolog Database. The system is capable of identifying aerobic bacteria, anaerobic bacteria, yeast as well as filamentous fungi.

System Benefits- No Gram stain is needed. One test panel IDs for both GN and GP bacteria. Set-up time in under a minute, accurate results in as little as 4 hours, Powerful RetroSpect software for trending and tracking.

Gen III Omnilog Id System (Preferred system for handling a large number of samples)- Gen III Omnilog Id System is an automated microbial identification system. It is provided along with Omnilog which is Plate reader cum Incubator. It is linked to a computer configured with software related to data collection and microbial identification software. A microplate loaded with suspension of test organism is incubated and read in Omnilog. The metabolic finger print is read and sent to the computer for recording and eventual comparative studies with profiles already stored in Biolog databases. Computer reports the species/genus when the metabolic finger print is matched with those present in Biolog Database. Omnilog can accommodate 50 Microplates simultaneously, with recording of the metabolic finger-print at 15 minutes interval in real-time thus making the microbial identification automated and high throughput. The system is capable of automated identification of aerobic bacteria only. It can be upgraded to undertake Phenotype Microarray.

Gen III Omnilog Plus Id System- The system is capable of automated identification of aerobic bacteria, and rapid identification of anaerobic bacteria, yeast as well as filamentous fungi.

Gen III Microlog M System (Manual System)- Microlog M is the Manual Version of Biolog's Microbial Identification System. It uses the same Gen III plate and Gen III Microbial Identification software, as are used in automated systems. Difference is that Computer and Plate Reader, are not provided in Manual System. Microbial culture is used to inoculate the Gen III plate, which is then incubated in a lab incubator. Plate is read for all the 96 tests manually in terms of Positive or Negative reaction (If color appears, it is positive otherwise negative). The plate results (positive or negative), are fed manually in Gen III software which is provided and loaded in a user provided computer. Software does the analysis, searches Biolog provided database, and then reports the species. You can also update the database with those genus/species which are not present in Biolog database (using an optional Retrospect). Manual system can be used for only aerobic bacteria.

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 "Diseases and Management of Crops under Protected Cultivation" scheduled on September 04-24, 2012.

1. Overall Supervision

Dr. K.S. Dubey, Director CAFTPP
Dr. R.P. Singh, Course Coordinator
Dr. H.S. Tripathi
Dr. R.P. Awasthi
Dr. V.S. Pundhir
Dr. (Mrs.) K. Vishunavat

2. Invitation, Inaugural and Closing Function Committee

Dr. H.S. Tripathi– Chairman
Dr. A.K. Tewari
Mr. Narender Singh
Mr. S.P. Yadav
Mr. Mani Ram

3. Inaugural Session, Intersession Tea and valedictory function Committee

Dr. Yogendra Singh – Chairman
Dr. (Mrs.) Deepshikha
Mr. S. P. Yadav
Mr. Jagannath
Mr. Mani Ram

4. Budget Committee

Dr. R. P. Awasthi – Chairman
Dr. Yogendra Singh
Mr. O.P. Varshney (A.O.)
Mr. A. B. Joshi
Mr. Praveen Kumar
Mr. Het Ram

5. Transport and Reception Committee

Dr. Pradeep Kumar – Chairman
Dr. S.K. Mishra
Mr. B.C. Sharma
Mr. P.C. Khulbe
Mr. Bhupesh Kabadwal
Mr. R.C. Singh

6. Boarding & Loading Committee

Dr. V.S. Pundhir – Chairman
Dr. R.P. Singh
Dr. S.K. Bansal
Mr. Mani Ram

7. Registration Committee

Dr. K.P. Singh – Chairman
Dr. Roopali Sharma
Dr. (Mrs.) Kanak Srivastava
Dr. (Mrs.) Renu Singh

8. Session Arrangement Committee

Dr. S.C. Saxean – Chairman
Dr. K.P. Singh
Dr. A.K. Tewari
Mr. Prakash Joshi
Mr. Vikram Prasad

9. Field / Excursion Trip Committee

Dr. Vishwanath – Chairman
Dr. Satya Kumar
Dr. L.B. Yadav
Mr. M.K. Sharma
Mr. K. S. Bisht
Mr. R. B. Sachan

10. Audiovisual Aid & Publicity Committee

Dr. K.P.S. Kushwaha-Chairman
Dr. Geeta Sharma
Mr. Praveen Kumar
Mr. Bupesh Kabdwal

11. Committee for typing correspondence work

Dr. A.K. Tewari, Chairman
Smt. Meena Singh
Mr. Gharbharan Prasad
Mr. Mehboob

ANNEXURE-II

LIST OF PARTICIPANTS

Sl. No.	Name and Address	Phone/E-mail
1.	Dr. Shailendra Singh Dhaka Asstt. Prof./ SMS (Plant Protection) Krishi Vigyan Kendra, Pilibhit S.V.Patel Univ. of Agri. & Tech., Meerut Pilibhit- 262 305 (UP)	(Mb.): 9412114409 E-mail: chssdhaka@gmail.com
2.	Dr. Rajendra Pratap Singh SMS-Plant Protection Krishi Vigyan Kendra, P.G. College Ghazipur- 233 001 (UP)	(O): 0548-2220059 (R): 09532460717, 08090618642 (Mb.): 09450764019 E-mail: kvk_ghazipur@rediffmail.com rpskvk.22@gmail.com
3.	Dr. Sanjai Kumar Singh Rajpoot SMS/Asstt. Prof. Plant Protection Ent. Krishi Vigyan Kendra, Masodha Faizabad-224 133 (UP)	(Mb.): 9450739207 E-mail: sksraj333@yahoo.com
4.	Dr. Jagdish Kishore SMS, Plant Protection Directorate of Extension C.S.A. Univ. of Agric. & Tech. Kanpur- 208 002 (UP)	(Mb.): 9415940548 (R): 0512-2582433 E-mail: jagdish.kishore13@gmail.com
5.	Mr. P. Palaiah Assistant Professor, Plant Pathology Agricultural Research Station Tq-Shorapur, Distt-Yadgiri Kawadimatti-585 290 (Karnataka)	(O): 08443-292384 (R): 08443-256118 (Mb.): 8105559675 8762564880 E-mail: plantcare@rediffmail.com
6.	Dr. (Mrs.) N. Rajinimala Assistant Professor, Plant Pathology Maize Research Station Tamil Nadu Agricultural University Vagarai- 624 613 District- Dindigul (TN)	(O): 04545-292900, 267373 (Mb.): 9442529808 E-mail: rajinimala@rediffmail.com
7.	Dr. (Mrs.) K. Kavitha Assistant Professor (Plant Pathology) Oilseeds Research Station Tamil Nadu Agricultural University District- Villupuram Tindivanam 604 002 (TN)	(O): 04147-250293 (Mb.): 09444054263 E-mail: kavipat_15@yahoo.com kavithagobi@gmail.com
8.	Dr. (Ms) S. Sundravadana Assistant Professor, Plant Pathology Sugarcane Research Station Tamil Nadu Agricultural University Melalathur- 635 806 (TN)	(O): 04171-220275 (R): 09486445793 E-mail: sundravadana@rediffmail.com

9.	Dr. (Mrs.) T.K.S. Latha Assistant Professor (Plant Pathology) Horticultural Research Station Tamil Nadu Agricultural University Kodaikanal- 624 103 (TN)	(O): 04542-240931 (Mb.): 9443320015 E-mail: tkslatha@gmail.com
10.	Dr. (Mrs.) K. Chitra Assistant Professor (Plant Pathology) Soil & Water Management Res. Institute Tamil Nadu Agriculture University Kattuthottam, Thanjavur-613 501 (TN)	(O): 04362-267619 (R): 04362-267487 (Mb.): 07598405585 E-mail: chitrapatho@gmail.com drchtra2005@yahoo.co.in
11.	Dr. R.L. Meena Asstt. Research Scientist (Pl. Pathology) Directorate of Research S.D. Agricultural University, S.K. Nagar Banaskantha- 385 506 (Gujarat)	(O): 02748-278233 (R): 09725222964 E-mail: ramji_meena@yahoo.com
12.	Dr. Bharatkumar R. Nakrani Assistant Research Scientist (Pl. Path.) Centre of Excellence for Research on Organic Farming S.D. Agricultural University Bhachau-Kachchh- 370 140 (Gujarat)	(O): 02837-223329 (Mb.): 09879480402 (R): 09979453396 E-mail: bharatnakrani69@gmail.com
13.	Dr. Sandeep Jain Assistant Professor Department of Plant Pathology Punjab Agricultural University (PAU) Ludhiana- 141 004 (Punjab)	(O): 0161-2400898, 2401960 (Mb.): 09872322880 E-mail: jainpau@yahoo.com sandeepjain@pau.edu
14.	Mr. Jagdish Prasad Bajia Assistant Professor Department of Plant Pathology Agriculture Research Station Durgapura, Jaipur- 302 018 (Raj.)	(O): 0141-2550391 (R): 0141-2546349 (Mb.): 09414991591
15.	Dr. Ram Phool Ghasolia Asstt. Prof., Department of Plant Pathology S.K.N. College of Agriculture Jobner, Jaipur- 303 329 (Raj.)	(O): 01425-254022 (R): 09772250146 (Mb.): 09414326672 E-mail: rghasolia@rediffmail.com
16.	Dr. (Mrs.) Sangita Sahni Assistant Professor, Plant Pathology Tirhut College of Agriculture, Dholi Rajendra Agricultural University Muzaffarpur- 843 121 (Bihar)	(O): 0621-2293227 (R): 08051099287 E-mail: sangitampp@gmail.com
17.	Dr. A.P. Suryawanshi Associate Professor, Plant Pathology Marathwada Krishi Vidyapeeth Parbhani- 431 402 (MS)	(O): 02452220755 (R): 08624865493 (Mb.): 09423736576 E-mail: apsmkv@rediffmail.com

18.	Dr. M. Rama Bhadra Raju Scientist (Plant Pathology) Agricultural Research Station (ANGRAU) RAGOLU Srikakulam District-532 484 (AP)	(O): 08942-279836 (Mb.): 09440880258 E-mail: mrbraju@yahoo.com
19.	Dr. Deepshikha Junior Research Officer Department of Plant Pathology College of Agriculture G.B.P.U.A.&T., Pantnagar- 263 145 (UK)	(O): 05944-233076 ®: 05946-281654 (Mb.): 8859065125 E-mail: deeppatho@rediffmail.com
20.	Dr. Dinesh Chandra Baskheti Junior Research Officer Deptt. of Genetics and Plant Breeding College of Agriculture G.B.P.U.A.&T., Pantnagar- 263 145 (UK)	(Mb.): 9412120982 E-mail: dcbaskheti@gmail.com
21.	Dr. P.K. Pandey JRO, Genetics and Plant Breeding College of Agriculture G.B.P.U.A.&T., Pantnagar- 263 145 (UK)	(R): 05944-233558 (Mb.): 9411377438 E-mail: drpradeepkpandey@gmail.com
22.	Dr. Poonam Srivastava Junior Research Officer Department of Entomology G.B.P.U.A.&T., Pantnagar- 263 145 (UK)	(O): 05944-233078 (Mb.): 9411159448 E-mail: poonamento@rediffmail.com

S U M M A R Y

Sl. No.	State	No. of participants
1	Andhra Pradesh	01
2	Bihar	01
3	Gujarat	02
4	Karnataka	01
5	Maharashtra	01
6	Punjab	01
7	Rajasthan	02
8	Tamil Nadu	05
9	Uttar Pradesh	04
10	Uttarakhand	04
	Total Participants	**22**

ANNEXURE-III

TRAINING

ON

DISEASES AND MANAGEMENT OF CROPS UNDER PROTECTED CULTIVATION

(September 04-24, 2012)

Venue	CAFT Hall, Plant Pathology
Sponsored by	Centre of Advance Faculty Training in Plant Pathology (ICAR, New Delhi)

GUEST SPEAKERS/CONTRIBUTORS

Dr. Alok Kalra	Scientist and Head, Microbial Technologies Division, Central Institute of Medicinal & Aromatic Plants, Lucknow (UP)
Dr. J.C. Bhatt	Director, VPKAS, Almora
Dr. U.S. Singh	Coordinator, South Asia, Bill & Melinda Gates Foundation (BMGF) Proj., International Rice Research Institute, New Delhi
Dr. Naved Sabir	Senior Scientist, National Cenre for IPM, IARI Campus, New Delhi
Dr. S.K. Dwivedi	Jt. Director, Centre for Personnel Tallent Management , Metcalf House, Delhi
Dr. V.K. Baranwal	Principal Scientist & In-charge, Plant Virology Unit, Division of Plant, Pathology, IARI, New Delhi
Dr. Suresh Pandey	Scientist, Internation Crops Research Institute, for the Semi-Arid Tropic (ICRISAT), Patancheru (AP)
Dr. Dinesh Singh	Senior Scientist, Division of Plant Pathology, IARI, New Delhi
Dr. Narayan Chawda	VNR Seeds, Village Gomchi (Near nandan Van), P.O. Tendua, Raipur (Chattisgarh)
Shri. Ravindra Mohan Sharma	Village Bhawan Singh Nawad, Haldu Chaur, Nainital

LOCAL SPEAKERS

Dr. J. Kumar	Dean, College of Agriculture
Dr. K.S. Dubey	Professor and Head-cum-Director CAFT Plant Pathology
Dr. S.C. Saxena	Honorary Professor, Plant Pathology
Dr. K.P. Singh	Emeritus Scientist, Plant Pathology
Dr. H.S. Tripathi	Guest Faculty, Plant Pathology
Dr. R.P. Awasthi	Professor, Plant Pathology
Dr. (Mrs.) K. Vishunavat	Professor, Plant Pathology
Dr. V.S. Pundhir	Professor, Plant Pathology

Dr. Pradeep Kumar	Professor, Plant Pathology
Dr. Vishwanath	Assoc. Prof., Plant Pathology
Dr. Y. Singh	SRO, Plant Pathology
Dr. R.P. Singh	SRO, Plant Pathology
Dr. K.P.S. Kushwaha	SRO, Plant Pathology
Dr. A.K. Tewari	SRO, Plant Pathology
Dr. Satya Kumar	SRO, Plant Pathology
Dr. L.B. Yadav	Assistant Professor
Dr. Roopali Sharma	JRO, Plant Pathology
Dr. S.K. Mishra	JRO, Plant Pathology
Dr. P.K. Singh	SRO, Irrigation and Drainage Engineering
Dr. J.P. Singh	Director Research & Professor, Vegetable Science
Dr. Dinesh K. Singh	Associate Professor, Vegetable Science
Dr. Dhirendra Singh	Associate Professor, Vegetable Science
Dr C.P. Singh	Professor, Horticulture
Dr. Santosh Kumar	Professor, Horticulture
Dr. Ranjan Srivastav	Associate Professor, Horticulture
Dr. Ajit Kapoor	Assistant Professor, Horticulture
Dr. Anjana Srivastava	Associate Professor, Chemistry
Dr. Alok Shukla	Professor, Plant Physiology
Dr. Anil Sharma	Associate Professor, Biological Science
Dr. Balwinder Singh	Associate Professor, Veterinary Anatomy
Dr. M.P. Singh	OIC, ZRS, Lohaghat

ANNEXURE-IV

CENTRE OF ADVANCED FACULTY TRAINING IN PLANT PATHOLOGY
G.B. Pant University of Agric. & Tech., Pantnagar-263 145 (UK)
Course Schedule (September 04-24, 2012)

"DISEASES AND MANAGEMENT OF CROPS UNDER PROTECTED CULTIVATION"

Venue : CAFT Hall, Department of Plant Pathology

Day & Date	Time	Topic of Lecture	Name & Designation of Speaker
Tuesday 4.9.2012	09:00-09:30 hrs	Registration Venue: PG Lab, Plant Pathology	Registration Committee
	09:30-10:00 hrs	Introduction with Plant Pathology Faculty Venue: PG Lab, Plant Pathology	Faculty Plant Pathology
	10:00-11:00 hrs	Inaugural Function Venue: Conference Hall, Agriculture College	
	11:00-11:15 hrs	Tea break	
	11:15-12:45 hrs	Visit to laboratories of Department of Plant Pathology	Dr. Y. Singh
	12:45-14:30 hrs	Lunch	
	14:30-17:00 hrs	Visit to University Research Centers	Drs. Vishwanath & R. K. Sahu, Professor
Wednesday 5.9.2012	09:30-10:30 hrs	College of Agriculture at a Glance	Dr. J. Kumar, Dean Ag.
	10:30-11:30 hrs	Department of Plant Pathology and CAFT activities at Pantnagar	Dr. K.S. Dubey, Director, CAFT
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Teacher's day celebrations	Students
	13:00-14:30 hrs	Lunch	
	14:30-17:00 hrs	Visit to KNSCCF	Dr. S.K. Mishra
Thursday 6.9.2012	09:30-10:30 hrs	Production and management of roses under green house	Dr. Santosh Kumar
	10:30-11:30 hrs	Integrated pest management in protected cultivation – problems and perspectives	Dr. H.S. Tripathi
	11:30-11:45 hrs	Tea break	
	11:45-13:00	TA settlement	Dr. R.P. Awasthi
	13:00-14:30 hrs	Lunch	
	14:30-15:00 hrs	Soil Solarization in field and plastic houses for the management of soil borne diseases	Dr. Yogendra Singh
	15:00-15:15 hrs	Tea break	
	15:15-17:00 hrs	Visit to MRTC & Bio-control lab	Drs. K.P.S. Kushwaha/ R.Sharma
Friday 7.9.2012	09:15-09:30 hrs	Group photograph (Ag. College Lawn)	Dr. R.P. Singh
	09:30-10:30 hrs	Decision tools for integrated pest management	Dr. V.S. Pundhir
	10:30-11:30 hrs	Diagnosis and Management of Bacterial wilt of Solanaceous Crops caused by *Ralstonia solanacearum*	Dr. Dinesh Singh, IARI
	11:30-11:45 hrs	Tea break	

	11:45-13:00 hrs	Planning, Design and Construction of Poly House / Protected Structure	Dr. P.K. Singh
	13:00-14:30 hrs	Lunch	
	14:30-17:00 hrs	Identification of the plant pathogens through PCR (Practical)	Drs. J. Kumar & Smita Puri
Saturday 8.9.2012	09:30-10:30 hrs	Protected cultivation in Indian and overview	Dr. Naved Sabir, NCIPM
	10:30-11:30 hrs	A glimpse of mushroom science and technology	Dr. S.K. Mishra
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Management of Greenhouse Mites	Dr. Naved Sabir, NCIPM
	13:00-14:30 hrs	Lunch	
	14:30-15:30 hrs	Management of nematode diseases under protected cultivation	Dr. Naved Sabir, NCIPM
	15:30-15:45 hrs	Tea break	
	15:45-17:00 hrs	Discussion with resource person	Dr. Naved Sabir, NCIPM
Sunday 9.9.2012		Visit to Singhal floritech, Tanda Mallu, Ramnagar, Singhal Farm, Jaspur, Vijay Singh's Farm, Kundeswari	Drs. Vishwanath, Assoc. Prof./C. Tewari (Extn.)
Monday 10.9.2012	09:30-10:30 hrs	Tomato Production in Greenhouse	Dr J.P. Singh, Director Research
	10:30-11:30 hrs	Climate Change and Plant Diseases	Dr. Suresh Pandey, ICRISAT
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Irrigation techniques for protected cultivation	Dr. P. K. Singh
	13:00-14:30 hrs	Lunch	
	14:30-17:00 hrs	Visit to MFC practical demonstration on flower production under poly house (Practical)	Dr. Santosh Kumar Jt. Director, MFC
		Visit to HRC for practical demonstration on precision fertigation system *(Practical)*	Dr. P. K. Singh
Tuesday 11.9.2012	09:30-10:30 hrs	An Overview on Seed-borne Diseases and Effective Protection against Them	Dr. K. Vishunawat
	10:30-11:30 hrs	Protected cultivation technology: Boon to hill farmers	Dr. K. P. Singh
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Chemigation under protected cultivation	Dr. P.K. Singh
	13:00-14:30 hrs	Lunch	
	14:30-15:30 hrs	Detection of seed borne pathogens of vegetables *(Practical)*	Dr. K. Vishunawat
	15:30-15:45 hrs	Tea break	
	15:45-17:00 hrs	Detection of seed borne pathogens of vegetables *(Practical)*	Dr. K. Vishunawat
Wednesday 12.9.2012	09:30-10:30 hrs	Biological control of soil borne pathogens under greenhouse conditions	Dr. J. Kumar, Dean Ag
	10:30-11:30 hrs	Hydroponics and plant disease management	Dr. Alok Shukla, CBSH
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Production and management of capsicum in green houses	Dr. Dhirendra Singh
	13:00-14:30 hrs	Lunch	

	14:30-17:00 hrs	Visit to VRC for practical demonstration on vegetable production under green house *(Practical)*	Dr. Dhirendra Singh/ Shri. Bhupesh Kumar
13.9.2012 Thursday	09:30-10:30 hrs	Protected cultivation: a farmer's experience	Shri. Ravindra Mohan Sharma
	10:30-11:30 hrs	Host -plant resistance to pathogens	Dr. V.S. Pundhir
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Production and Management of Gerbera under Protected Conditions	Dr. Ranjan Srivastav
	13:00-14:30 hrs	Lunch	
	14:30-17:00 hrs	Use of BIOLOG microbial identification for diagnosing bacterial pathogens in protected cultivation *(Practical)*	Drs. R.P. Singh & Smita Puri
Friday 14.9.2012	09:30-10:30 hrs	Preventive measures for managing diseases under green houses	Dr. R. P. Singh
	10:30-11:30 hrs	Biocontrol of Foliar Plant Pathogens under Protected Cultivation	Dr. A. K. Tewari
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Compost: Its Microbiology and Disease Management	Dr. Anil Kumar Sharma
	13:00-14:30 hrs	Lunch	
	14:30-15:30 hrs	Challenges of transfer of diseases management technology in hill agro ecosystem	Dr. R.P. Singh
	15:30-15:45 hrs	Tea Break	
	15:45-17:00 hrs	Mass production of biocontrol agents *(Practical)*	Drs. A. K. Tewari & Roopali Sharma
Saturday 15.9.2012	09:30-10:30 hrs	Protected Cultivation Technology- The Developmental and Innovative Perspective	Dr. S.K. Dwivedi, DRDO
	10:30-11:30 hrs	Interaction with Dr. Alok Kalra (ICAR Observer)	Director, CAFT
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Innovations in protected cultivation technology	Dr. S.K. Dwivedi, DRDO
	13:00-14:30 hrs	Lunch	
	14:30-15:30 hrs	Role of protected cultivation in hill agriculture	Dr. J.C. Bhatt, Director, VPKAS, Almora
	15:30-15:45 hrs	Tea break	
	15:45-17:00 hrs	Guest Lecture	Dr. Alok Kalra, CIMAP
Sunday 16.9.2012		Visit to university library	
Monday 17.9.2012	08:00-18:00 hrs	Visit to Plantis agro-tech kainchi, Nainital	Drs. R.K. Sahu & L.B. Yadav
Tuesday 18.9.2012	09:30-10:30 hrs	Vegetable grafting for managing soil borne diseases of solanaceous crops	Dr. Narayan Chawda, VNR Seeds, Raipur
	10:30-11:30 hrs	Vegetable grafting for managing soil borne diseases of cucurbitaceous crops	Dr. Narayan Chawda, VNR Seeds, Raipur
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Pantnagar at a glance	Dr. S.C. Saxena
	13:00-14:30 hrs	Lunch	

	14:30-15:30 hrs	Use of electron microscope for detection and diagnosis of pathogens in protected cultivation	Dr. Balwinder Singh
	15:30-15:45 hrs	Tea break	
	15:45-17:00 hrs	Detection of plant pathogens/ viruses by electron microscopy (Practical)	Dr. Balwinder Singh
Wednesday 19.9.2012	09:00-10:00 hrs	Management of abiotic stress in rice	Dr. U.S. Singh, IRRI
	10:00-11:00 hrs	Production of virus free vegetables by using insect proof nets	Dr. Narayan Chawda, VNR Seeds, Raipur
	11:00-11:15 hrs	Tea break	
	11:15-13:00 hrs	Management of Plant viruses under greenhouse	Dr. V. K. Baranwal, IARI
		Molecular tools for virus indexing of vegetatively propagated crops	Dr. V. K. Baranwal, IARI
	13:00-14:30 hrs	Lunch	
	14:30-15:30 hrs	Evaluation of risks related to the release of biocontrol agents active against plant pathogens	Dr. J. Kumar
	15:30-15:45 hrs	Tea break	
	15:45-17:00 hrs	Production and management of chrysanthimum under green house	Dr. Ajit Kapur
Thursday 20.9.2012	09:30-10:30 hrs	Production of quality planting material under protected environment	Dr C.P. Singh
	10:30-11:30 hrs	Commercial Aspect of Biocontrol of Pest & Diseases	Dr. A K Tewari
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Production and management of cucurbits in green houses	Dr. Dinesh K. Singh
	13:00-14:30 hrs	Lunch	
	14:30-15:30 hrs	Monitoring and decontamination of pesticide residue in farm gate vegetables	Dr. Anjana Srivastava
	15:30-15:45 hrs	Tea break	
	15:45-17:00 hrs	Estimation of pesticide residue in farm gate vegetables through HPLC *(Practical)*	Dr Anjana Srivastava
Friday 21.9.2012	08:00 hrs	Departure to Indo-dutch Project, Chafi, Bhimtal	Drs. K.P.S. Kushwaha & S.K. Mishra
	11:00-12:00 hrs	Production of bulbous flowers under protected structures	Shri. Sudheer Chadha
	12:00-12:15 hrs	Tea break	
	12:15-13:30 hrs	Visit to Indo-dutch Project	Shri. Shushan Chadha
	13:30-14:30 hrs	Lunch	
	14:30 hrs	Departure to Lohaghat	
Saturday 22.9.2012	09:30-11:00 hrs	Visit to ZRS/KVK, Lohaghat	Dr. V.K. Singh
	11:00-11:15 hrs	Tea break	
	11:15-12:45 hrs	Transfer of protected production technology to hill farmers	Dr. M.P. Singh
	12:45-14:30 hrs	Lunch	
	14:30-15:30 hrs	Production of off season flowers and vegetables in hills under protected cultivation	Dr. Ajay

	15:30-15:45 hrs	Tea break	
	15:45-17:00 hrs	Visit to farmers field	Dr. M.S. Gangwar
Sunday 23.9.2012	08:00 hrs	Departure to Pantnagar	
Monday 24.9.2012	09:30-10:30 hrs	Diseases of Vegetable Crops under Protected Cultivation	Dr. R. P. Singh
	10:30-11:30 hrs	Presentation by participants	
	11:30-11:45 hrs	Tea break	
	11:45-13:00 hrs	Presentation by participants	
	13:00-14:30 hrs	Lunch	
	14:30-15:00 hrs	Discussion with faculty	Faculty Pl. Path.
	15:00-16:30 hrs	Closing ceremony	