VEGETABLES

Disease Diagnosis and Biomanagement

Pratibha Sharma

VEGETABLES : DISEASE DIAGNOSIS AND BIOMANAGEMENT

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INTRODUCTION

FOOD SECURITY

Out of the three components of Food, Nutrition and Environmental Security the first—Food has been the major concern for nearly two-third of the past century from the beginning. But now, when we look to past, we would find that growth in technology-led food grains production in the country has convincingly finished ahead of the population growth despite some gloomy Malthusian predictions. Beginning from net food deficit for nearly 350 million Indians at the time of independence in the mid twentieth century, there has been a marginal surplus of food grains in the country for over 1 billion population at the turn of the century. The recorded Production and Demand in the year 2000-01 stood at 209 and 197 million tonnes, respectively.

Besides the enhanced availability of food from crops sub-sector, its diversification and thereby availability from the animal, fish and poultry sub-sector, also on the rise. The per capita per year availability of food items other than food grains has considerably increased. Between 1980-81 to 1999-00, it increased in the case of oilseeds and vegetable fats from 5.0 to 9.2 kg, in sugar from 7.3 to 15.6 kg, milk 46.7 to 77.9 kg, eggs from 17 to 31 in number, and fish from 3.4 to 5.6 kg. The corresponding figures for fruits and vegetables, from 1990-91 to 1999-00, are 34.1 to 43.9 kg and 68.1 to 87.4 kg, respectively. In India, the future obviously belongs to agriculture. By 2020, our dream is to make India a developed nation through agricultural growth. Agriculture is intended to become not merely an efficient, eco-friendly production system, capable of meeting basic demands of the rapidly increasing population, but it has to become a major powerful instrument for a comprehensive socio-economic transformation of the country, including improvement in the quality of life of every individual. This is an exciting opportunity and a challenging responsibility.

It is reliably estimated that in the year 2020, under the scenario of 5 percent growth in GDP, the total domestic foodgrains demand will be 294 million tonnes (mt) comprising 122 mt of rice, 103 mt of wheat, 41 mt of coarse grains and 28 mt of pulses. Similarly, during 2020, the demand will be 126-183 mt of milk, 136-181 mt of vegetables, 68-98 mt of fruits, 6.3 to 12.1 mt of meat and 9.5-18.3 mt of fish. To meet the estimated demand, the yield level over the base period yield (1994-95) is required to be enhanced by 56 percent for rice, 62 percent for wheat, 36 percent for coarse cereals, and 116 percent for pulses. Similarly, the production of livestock and poultry products must be enhanced to 136-157 percent. Considering these uptrends, National Agricultural Policy rightly envisages growth rate in excess of 4 percent per annum in agriculture sector, which is higher than even the highest decadal (1979-80/1989-90) growth rate (3.54%) achieved so far. It should be noted here that these growth targets are to be achieved against the constraints of diminishing land resources, increasing biotic and abiotic stresses, indications of decline in factor productivity, threatened loss of biodiversity, natural resource shrinkage and degradation, climate change, tightening of IPR, intensifying competition (quality and cost) international trade, widening economic inequality besides burgeoning population. Thus, producing food to banish hunger and to provide employment and income for buying food, remain our biggest challenge in the coming years. It is strongly felt that increasing agricultural growth is the only way for alleviating poverty, increasing employment and income, providing food, protecting the environment and overall economic transformation of rural India.

The very first that may be recorded for affecting transformation in the food scenario was the discovery of dwarfing genes in the two major cereal crops - rice and wheat. Their judicious and efficient use has contributed in a long way towards the attainment of food self-sufficiency, in particular, their free exchange, successful incorporation in to the cultivated varieties, building up scientific data for their performance, taking foresighted decisions for their large scale seed production and front-line extension programme, making provision for additional requirement of fertilizers through production, subsidy and credit, timely declaration of minimum support prices for the grains produced, etc. have all worked well.

The requirements in the 21st century would be to now maintain the surge of food availability from production. In this context, we have witnessed concerns for yield plateau, limitations in having more areas under agriculture, water scarcity and reduction in the quality of ground, particularly in the major productive areas under food grains, several other limiting factors. On the other hand, a more optimistic picture is presented by the rise of biotechnology, which has emerged as a powerful tool to harness plant productivity through unconventional means. In the 21st century, an effective use of this important contributing factor can be utilized in order to innovate and improvise cheaper and indigenous protocols for standardization and use of bio-cultures for the benefit of agriculture. We should also look forward to discover and new genes from our rich micro-flora from the well-established traditional-farming, which clearly foster harmony between plants-animals-humans and agriculture-friendly flora and fauna, particularly the soil micro-flora.Hybrid technology is also emerging as a successful tool in non-traditional way, for example in the self-pollinated crops, and it has become source of development in the 21st century to enhance our food production.

The tremendous opportunity and support to enhance food production in the country must be consolidated and enhanced in the 21st century with mutual support by partners from public, non-government and private. A research base has been reasonably well established to enlarge the national food basket from promotion of some life support species and marginal crops. We must make more intensive efforts to further short-list, project and popularize such crops and their improved varieties in order to ensure more food security.

The need of having quicker and efficient tools for the verification of performance of new varieties, and in particular standardizing and fixing their packages of agronomic practices is reiterated and this requires perpetual attention with more focused thrust. It may be quicker to incorporate a new gene with precision but, at the same time, is also important to judge and standardize the adaptability and responsiveness limits of new varieties thus evolved. This would help farmers to economise their production, and avoid wastage of money and depletion of resources through run-off or leaching. In order to get maximum advantage of new technology for more food production, these basics of agriculture should be fully understood and further exploited in the 21st century as they were being used ever before.

STATUS OF VEGETABLE REASEARCH AND PRODUCTION

India has taken a bold step towards self sufficiency in food. However, self sufficiency in the true sense can be achieved only when each individual in the country is assured of balanced diet. Varied agro-climatic conditions in India make it possible to grow a wide variety of vegetable crops all the year round in one part of the country or another. India can claim to grow the largest number of vegetable crops compared to any other country of the world and as many as 61 annual and 4 perennial vegetable crops are commercially cultivated. Some of the important vegetable crops grown are:

Solanaceous crops	–	Brinjal, tomato, chillies, sweet pepper (Capsicum)
Cole crops	–	Cabbage, cauliflower, knol khol
Bulbous vegetable	–	Onion, garlic
Okra	–	Okra
Cucurbits	–	Longmelon, muskmelon, snapmelon, watermelon, cucumber, pumpkin, summer squash, bitter gourd, bottle gourd, pointed gourd (parwal), ridge gourd, round gourd, snake gourd, sponge gourd, wax gourd (ash gourd)
Root vegetables	–	Carrot, radish, turnip
Leguminous vegetables	–	Broad bean, cluster bean, cowpea, dolichos bean, French bean, peas
Leafy vegetables	–	Amaranthus, beet leaf, fenugreek, spinach
Salad vegetables	–	Lettuce
Perennial vegetables	–	Drumstick, curry leaf, agathi, paii

India is the second largest producer of vegetables in the world next only to China with an estimated production of about 50.09 million tonnes from an area of 4.5 million

hectares at an average yield of 11.3 tonnes per hectare. India shares about 12% of the world output of vegetables from about 2.0% of croppped area in the country. Statewise area and production of vegetable crops and area and production of different vegetable crops in India is given in Tables (1-4) respectively. The per capita consumption in India is only about 140 gm which is far below the minimum dietary requirement of 280 g/ day/person. In the independent India, systematic efforts have been made to upgrade vegetable production technology. However, such efforts were quite inadequate due to priority given to food grain production programmes so far. Inspite of this vegetable production India has steadily increased from about 28 m.tonnes during 1969-71 to its present level. The demand of vegetables has been increasing fast in the urban areas with a gradual rise in standard of living coupled with development of communication and transport facilities. It therefore calls a major research and development effort to achieve our target (83 million tonnes) for the supply of 200 gms of vegetables per capita per day to an estimated population of 1 billion by 2000 A.D. through suitable research programmes. These programmes need to focus on the crop protection problems which cause serious losses to the crops in field and storage.

TABLE 1

All India production of horticultural crops (2002-03)

Horticulture crops	Production (m tones)	Production (%)
Fruits	45.203	31.31
Vegetables	84.815	58.74
Flowers	0.735	0.51
Nuts	0.114	0.08
Spices	3.765	2.61
Plantation crop	9.697	6.72
Honey & Mushroom	0.050	0.03

National Horticulture Board, 2003

TABLE 2

All India area, production and productivity of vegetable crops

Year 1	Area (m ha) 2	Production (m tones) 3	Productivity (t/ha) 4
1991-92	5.593	58.532	10.5
1992-93	5.045	63.806	12.6
1993-94	4.876	65.787	13.5
1994-95	5.013	67.286	13.4
1995-96	5.335	71.594	13.4
1996-97	5.515	75.074	13.6
1997-98	5.607	72.683	13.0
1998-99	5.873	87.536	14.9

Contd...

1	2	3	4
1999-2000	5.991	90.823	15.2
2000-01	6.250	93.849	15.0
2001-02	6.156	88.622	14.4
2002-03	6.092	84.815	13.9

National Horticulture Board, 2003

TABLE 3

Crop wise area, production and productivity of major vegetable crops in India (2002-03)

Crops	Area (m ha)	Production (m tones)	Productivity (t/ha)
Brinjal	507.3	8001.2	15.8
Cabbage	233.8	5392.0	23.1
Cauliflower	254.6	4444.1	17.5
Okra	329.2	3244.5	9.9
Onion	424.7	4209.5	9.9
Pea	305.2	2061.8	6.8
Potato	1337.2	23161.4	17.3
Sweet potato	131.9	1130.3	8.6
Tapioca	207.0	5426.2	26.2
Tomato	478.8	7616.7	15.9
Others	1882.0	20127.6	–
Total	6091.7	84815.3	13.9

National Horticulture Board, 2003

DISEASE LOSSES AND CROP PROTECTION

Vegetable crops including solanaceous, cucurbitaceous, brassicaceae, leguminous, bulb crop, root crop as well as green leafy vegetables and some other vegetables are attacked by number of pathogen like fungi, bacteria, virus, nematode as well as abiotic stress like temperature, soil moisture, inadequate oxygen supply, air pollution, nutritional deficiency, herbicidal injury and other improper agricultural practices. An overview of the literature indicates that some diseases such as potato late blight, purple blotch of onion, downy mildew, powdery mildew, rust, Alternaria blight, blast, root rot, root knot nematodes, mosaic and those caused by non parasitic and parasitic agencies, can cause extensive losses in vegetable crops and are important throughout the vegetable growing areas, other diseases such as white rust of crucifers, okra mosaic, Stemphylium leaf blight in onion, Phomopsis blight, anthracnose of chilli are important in localized geographical areas. In view of large number of diseases, their wide distribution and the capacity of several diseases to cause extensive crop damage, it is apparent that losses in vegetable crop production would be much higher in the absence of disease management practices. The major constraint limiting factor limiting the higher productivity of the crop is the development of insect pests and diseases, which are favoured by intensive agriculture.

TABLE 4

Statewise area, production and productivity of vegetable crops

States/Union Territory	Area (m ha)				Production (m tones)				Productivity (m tones/m ha)			
	1991-92	2000-01	2001-02	2002-03	1991-92	2000-01	2001-02	2002-03	1991-92	2000-01	2001-02	2002-03
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
West Bengal	456.0	1075.0	1139.0	1208.5	4680.0	17779.4	18075.3	17376.5	10.3	16.5	15.9	14.4
Uttar Pradesh	576.0	668.1	777.9	853.5	9627.3	13030.4	15044.8	15791.4	16.7	19.5	19.3	18.5
Bihar	843.3	707.8	578.9	6.9.9	8643.1	10219.7	8022.9	8288.5	10.2	14.4	13.9	13.6
Orissa	710.3	702.5	643.4	616.8	7275.0	8089.1	7447.4	7126.2	10.2	11.5	11.6	11.6
Maharashtra	241.1	409.0	402.4	405.0	4171.3	5142.0	5128.3	4768.9	17.3	12.6	12.7	11.8
Tamil Nadu	889.3	220.2	213.8	166.6	3796.9	5939.3	5444.6	4223.3	4.3	27.0	25.5	25.3
Karnataka	351.1	343.7	358.1	354.0	3673.2	5763.0	4173.2	3707.9	10.5	16.8	11.7	10.5
Gujrat	114.6	205.6	232.2	248.3	1667.9	3070.8	3278.2	3517.9	14.6	14.9	14.1	14.2
Kerala	202.1	114.8	114.3	112.7	3229.1	2530.9	2541.9	2547.4	16.0	22.0	22.2	22.6
Assam	222.4	238.3	237.4	232.0	2132.3	2693.1	2935.2	2464.4	9.6	11.3	12.4	10.6
Andhra Pradesh	155.2	249.9	222.5	213.3	1452.6	3147.7	2586.7	2357.9	9.4	12.6	11.6	11.1
Punjab	84.5	131.0	135.0	138.3	1450.0	2310.0	2275.6	2319.4	17.2	17.6	16.9	16.8
Haryana	60.8	141.7	150.4	163.1	877.0	2191.5	2151.9	2051.8	14.4	15.5	14.3	12.6
Madya Pradesh	176.4	238.5	136.4	136.8	2221.0	3501.9	1817.5	1827.0	2.6	14.7	13.3	13.4
Chattisgarh	-	84.2	104.1	97.1	-	1146.3	1355.3	1357.2	-	13.6	13.0	14.0
Jharkhand	-	149.8	158.5	118.2	-	2109.5	1736.3	1300.1	-	14.1	11.0	11.0
Himachal Pradesh	38.7	44.8	34.6	44.3	476.0	734.2	639.4	775.7	12.3	16.4	18.5	17.5
Delhi	55.0	114.8	111.0	43.3	627.8	862.7	747.4	628.1	11.4	7.5	6.7	14.4
Uttaranchal	57.1	104.8	93.8	70.6	617.6	1138.1	737.3	507.5	10.8	10.9	7.9	7.2

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Tripura	30.3	31.8	31.3	31.6	306.8	328.1	353.2	360.3	10.1	10.3	11.3	11.4
Rajasthan	62.9	95.1	99.3	90.3	307.0	386.4	432.5	358.3	4.9	4.1	4.4	4.0
Meghalaya	25.9	37.7	35.7	38.1	219.2	303.6	265.9	338.9	8.5	8.1	7.4	8.9
Jammu & Kashmir	180.3	45.7	50.8	24.9	745.0	757.9	728.9	332.9	4.1	16.6	14.4	13.4
Arunachal Pradesh	17.1	21.0	20.8	20.5	79.9	83.7	83.9	81.5	4.7	4.0	4.0	4.0
Nagaland	8.2	26.9	26.3	6.7	66.9	253.6	286.0	78.5	8.2	9.4	10.9	11.7
Manipur	11.8	9.7	10.6	11.6	50.3	67.4	66.1	71.9	4.3	6.9	6.2	6.2
Goa	-	7.6	7.6	7.0	-	76.0	76.0	68.5	-	10.0	10.0	9.8
Pondicherry	2.3	3.7	3.7	4.1	22.3	54.2	54.2	63.7	9.7	14.6	14.6	15.5
Sikkim	7.6	13.5	14.2	14.1	46.1	59.7	60.0	59.1	6.1	4.4	4.2	4.2
Mizoram	6.0	7.9	6.8	4.3	31.8	47.3	44.1	31.9	5.3	6.0	6.5	7.4
Andaman & Nicobar	3.4	3.1	3.1	3.6	13.2	15.8	15.8	16.3	3.9	5.1	5.1	4.5
Dadra & Nagar Haveli	1.5	1.5	1.5	1.5	13.6	13.5	13.5	13.5	9.1	9.0	9.0	9.0
Chandigarh	0.3	0.1	0.1	0.1	11.1	1.7	1.7	1.7	37.0	17.0	17.0	17.0
Daman & Diu	0.1	0.1	0.1	0.1	0.3	1.1	1.1	1.1	3.0	11.0	11.0	11.0
Lakshadweep	0.4	0.2	0.2	0.2	0.4	0.2	0.2	0.2	1.0	1.0	1.0	1.0
Total	5592.7	6250.1	6155.7	6091.8	58532.0	93849.8	88622.0	84815.4	10.5	15.0	14.4	13.9

National Horticulture Board, 2003

The most effective and sustainable control of the disease is obtained when different disease management strategies are integrated together. If proper crop husbandry practices are followed starting from sowing till vegetable crops reach to the consumer, losses can be minimized. Pathogen which invade the vegetable crops in the field and develop during storage can be checked by following proper cultural practices and pre harvest application of chemical. The use of resistant varieties is of immense value and some efforts have been made in this direction. Use of fungal and bacterial antagonist along with other disease management strategies may emerge out as alternative approach to chemical control in near future.

Man has disturbed the natural ecosystem just enough to give the parasite and predators an upper hand. He set the stage for pests and pathogens to prosper the day he began to cultivate the soil so that crop could grown repeatedly on the same land, when he abandoned mixed vegetation in favour of intensive monoculture or culture of selected crop and began to breed crops to uniform standards of growth and physiology. The most dramatic episode of Irish famine caused by loss of genetic diversity in staple food crop occurred in summer of 1846, nearly 160 years ago when due to narrow down of the genetic base of potato in Ireland to the point where it had very little resistance to late blight, the entire crop was lost.

Plant diseases are important because of the loss they cause to the grower. The loss can occur in the field or in the store and at any time between sowing and consumption of the harvest. A disease attacks standing crop in the field and plants start drying or their capacity to yield satisfactorily is reduced. The farmers get only a portion of the estimated yield. He loses not only the yield but also the cost in raising the lost plants. The word management conveys the concept of a continuous process. It implies that disease is inherent component of an agro ecosystem that must be dealt with on a continuous knowledgeable basis. Management is based not on the principle of only eradication of the pathogen but mainly on the principle of maintaining the damage or loss below an economic injury level on at least minimizing occurrence of a disease above that level. Management suggests need for continuous adjustment in the cropping system.

Disease management practices are desirable only when the cost in terms of money and efforts is materially less than the loss expected from the disease so that the grower is ensured a margin of profit from the plant measures. An appreciable success has been achieved in production of vegetables in India and intensive efforts are being made to increase the production of horticultural crops in order to fulfill the domestic demands and to earn foreign exchange by exporting the produce. Intensive cultivation on the other hand, provided opportunities to many minor pathogens to become major and to major pathogen for development of frequent epidemics in certain crops. A number of pathogens have become endemic to the producing areas like late blight of potato, *Phytophthora, rots and lights mildews, wilts* caused diseases of many vegetables etc. The actual losses being incurred due to these major pathogens have not been estimated and thus the potential of these pathogens causing economical losses to the nation is still to be projected to check their further spread and to develop their effective integrated management.

Plant pathogens have great impact on the economy of the nation when there are periodic outbreaks of certain diseases, severe crop losses leading to famine, misery and

human suffering. Horticultural production in India is greatly affected with inadvertent introduction of pathogens to virgin areas due to lack of effective inter and intrastate quarantine network, paucity of disease free, elite planting material and ignorance of growers regarding damaging potential of the pathogens.

In post GATT and patenting era, there is an urgent need to define and confine the boundaries of major pathogens in other countries. The plant pathologists have great responsibility to workout the epidemiological factors related to major pathogens discussed above in order to develop computerized prediction models in the management of major diseases and losses caused by them like *Phytophthora* diseases of tomato and potato; blights, downy mildew and anthracnose of cruciferous vegetables; purple blotch of onion, wilt of cucurbits etc. Mostly studies have been confined to screen the germplasm for resistance and evaluation of chemicals for control of diseases. Plant pathologists and breeders are required to join hands in searching the resistance and in using the already identified resistance to develop resistant cultivars.

Management of post-harvest pathogens of vegetables has not been given due attention, which they actually deserve. High post-harvest losses due to rots, molds require their effective management technologies to reduce losses and to increase shelf life for domestic and export market. Soil solarization and screening of biocontrol agents are required for soil borne pathogens like *Phytophthora, Fusarium* etc. whereas for the control of post-harvest diseases, the use of post-harvest chemicals is being discouraged in many countries, hence the biocontrol agents are the only solution for managing post-harvest diseases of fruits and vegetables.

Different approaches to disease control have been evaluated in order to reduce the incidence of diseases caused by various soil borne and foliar pathogens in several crops. Cultural practice and application of fungicides are currently in practice in many areas. Extensive use of plant protection chemicals and some times their indiscriminate use have led to serious social and environmental repercussions. The poisoning of livestock, fish, wild life and their beneficial organisms has been due to increase use of these chemicals. There has also been disturbing increase in human poisoning, particularly in developing countries, where safe handling and application of plant protection chemicals are not always feasible due to several socioeconomic factors. Moreover, some of the chemicals are very expensive and can not be afforded by Indian farmers. In addition, the chemicals are required to be applied at intervals and in large quantities to treat the soil, results in increased cost of cultivation. Thus, increasing awareness of environmental and socioeconomic problems from the use of fungicides has encouraged the search for more biologically sound alternatives.

Several antagonists of microbial origin are successfully employed in the biocontrol of plant pathogens. Mostly they belong to fungal, bacterial or protozoan origin and are saprophytic in nature. Certain fungal antagonists such as *Trichoderma, Gliocladium* have been widely used on large scale to control fungal and bacterial diseases. Similarly, the fluorescent *Pseudomonas* and *Bacillus* spp. has very wide host range and are used to manage the plant diseases of fungal and bacterial origin.

Organic farming is the need in the present day context of serious threat to our ecology and environment. Great harm is being caused due to large-scale pollution of our

soil, water and air, which have resulted in degradation, and loss of these natural resources and a declining trend has set in the productivity of our soils. Chemical-agriculture with a heavy dependence on fertilizers and pesticides is affecting the quality and safety of produce and health and well being of humanity. For a sound future, organic farming offers a dynamic interaction between soil, plants, animals, humans, ecosystem and environment.

Integrated Pest Management is the latest buzz word in the field of crop protection today. Different IPM modules for key crops are being prepared for demonstrations in various states in the country involving various stakeholders. This is certainly a welcome development but what is more important is to assess how much prepared are the ultimate users of the IPM technology viz. The farmers?

The first and a very important target of making this technology successful is to train the users of this technology initially at least in few basic elements like:

- Diagnosis of disease symptoms and insect damage.
- Proper identification of various stages of life cycle.
- Identification of beneficial microflora and biocontrol agents.
- Assessment of economic losses due to pest damage.
- Development and Adoption of need based plant protection strategies including cultural, chemical, biological and resistance for the adopted cropping systems.
- Maintenance of the records of the pest damage.

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METHODS OF DIAGNOSIS

Disease diagnosis is the process of disease identification. Plants should be initially examined in the field, landscape, or garden setting, and the site, plant and problem history should be determined and recorded. If the plant disease or other problem cannot be diagnosed in the field setting, a plant sample should be collected, packaged, and mailed so that the sample arrives at a diagnostic laboratory or clinic in a fresh condition with an adequate quantity of symptomatic tissue for examination and testing. The sample must be representative of the problem. Initial diagnostic techniques may involve visual study, use of references, soil pH analysis, total soluble salt analysis and microscopy. Additional specialized procedures used (including culture work, serology and molecular testing) depend on the disease suspected, the value of the crop, and the client. A diagnosis is typically based on more than one procedure.

Disease diagnosis is the act or process of biotic or abiotic disease identification. Disease may be biotic or abiotic. Some plant disease agents cause visible symptoms distinct enough to allow for disease identification to be made relatively quickly on the basis of a visual study of only plant appearance. For example, powdery mildew symptoms can be well understood, likewise rotting or wilting can be well understood. However, in many situations, visual appearance of the diseased plant is not plain enough to allow for an exact diagnosis of the problem. In these cases, diagnosis depends on one or more assays or tests in addition to a visual inspection of the plant. These added studies might involve soil pH testing, soil analysis (total soluble salt and fertility and nematode assays), light and electron microscopic study of the damaged plant tissues, cultural and physiological studies of the isolated pathogen, molecular studies of the pathogen [serology, gel electrophoresis, gas chromatography, PCR (polymerase chain reaction), and DNA probe identification], plant tissue analysis, and soil or pathogenicity studies. The exact procedures used to diagnose a plant disease depend on the suspected disease and the plant or crop

situation. The crop situation or the crop owner often dictates the level of specificity needed in the diagnosis. For a backyard garden, the identity of a leaf spot may be sufficient, but with the leaf spot damage in a field situation, the identity of the leaf spot needs to be more specific, and the leaf spot would be identified by genus and species.

The process of disease diagnosis has existed, in some form, since diseases were first recognized. The Romans were aware of rust diseases of small grains as early as 310 BC. The actual cause of rust diseases and other plant diseases was not known or objectively studied until after the development of the compound microscope in 1675. Pasteur and other early scientists in the mid 1800s dispelled the earlier belief of spontaneous generation and proved that microorganisms were present in our environment and were responsible for many diseases of plants and animals. Debary in 1861 was the first to scientifically prove that the fungus *Phytophthora infestans* caused the disease of Irish potato called late blight, which had caused a widespread famine in Ireland in 1845 to 1846 . Since that time many biotic plant diseases have been identified and most are caused by fungi, bacteria, viruses and nematodes. The abiotic diseases are caused by such factors as temperature extremes, moisture extremes, low or high soil pH, fertilizer excesses or deficiencies, pesticide damage,pollution effects, or weather/soil problems.The hundred years following DeBary's first plant disease identification had been very active in the area of new disease diagnosis. The procedure used to confirm the existence of a new plant disease was developed by Anton Kochin 1876 and is known as Koch's postulates or proof of pathogenicity. This procedure is still used today for the diagnosis and identification of a new (previously unreported) plant disease. The procedure involves the following four steps:

1. The pathogen must be found with all symptomatic plants.
2. The pathogen must be isolated and grown in pure culture and its characteristics described. If the pathogen is a biotroph, it should be grown on another host plant and have the symptoms and signs described.
3. The pathogen from pure culture or from the test plant must be inoculated on the same species or variety as it was originally described on and it must produce the same symptoms that were seen on the originally diseased plants.
4. The pathogen must be isolated in pure culture again and its characteristics described exactly like those observed in Step 2. This procedure was ammended by Robert Smith to include reisolation of the pathogen from the inoculated, symptomatic plant. If both cultures contain the same microorganism, then this organism is considered to be the pathogen or cause of the disease.

Today, Koch's postulates or proof of pathogenicity procedures include the last step added by R. Smith (Agrios, 1997). Most of the plant disease diagnosis done today involve identification of plant diseases that have been previously described and named. Several techniques may be performed to determine the identity or causal agent (pathogen) of a disease. These diagnostic procedures are completed by or under the direction of plant pathologist diagnosticians. These procedures or analyses may include many of the ones mentioned earlier in this chapter. PCR techniques are not routinely used in clinics, but recent advances in molecular methods, such as kits for PCR DNA hybridization, may be

available for clinical use in pathogen detection and identification in the near future (Schaad et al., 2001). The PCR methodology will allow for pathogen identification from very small samples. Visual studies of symptoms and signs, microscopy, culture media studies, and serology techniques are the most frequently used techniques in diagnostic clinics. Disease diagnosis may involve one or more procedures, depending on the disease, the client, and the planting situation.

Today in the era of Molecular Plant Pathology this branch of Plant Pathology is becoming uninteresting and students need to work on this also because the farmer fields remain under the pressure of the pathogens. This chapter describes the basic steps involved in plant disease diagnosis from the time the abnormality is noticed in the field or landscape until the diagnosis is accomplished. Today researchers are developing molecular diagnostic kits, but how many would work under Indian conditions and therefore, classical methods along with the modern tools are required to be understood.

ISOLATION OF THE PLANT PATHOGEN ON CULTURE MEDIA

When fungal disease is suspected and microscopic evidence is not present, moist chamber incubations are often used first. Culture work is used if the moist chamber technique is not successful for fungal identification or if bacterial pathogen identification is desired. Tissue used in isolations in culture media must be fresh, consisting of recently infected tissue areas bordering on healthy tissue. Tissue to be cultured is usually surface sterilized with a 10% (v/v) solution of household bleach. The duration of surface sterilization ranges from a few seconds to 2 min. Immediately after soaking the tissue pieces in the bleach solution, the tissue should be rinsed in sterile distilled or filtered water. Tissue should then be blotted dry (clean paper towels usually work fine for blotting). Tissue sections should be aseptically cut into small pieces (2-3-mm diameter) and placed into sterile culture medium in sterile petri dishes. Dishes are usually maintained at room temperature for 3 to 7 days and examined daily for fungal growth. Potato dextrose agar acidified with lactic acid to retard bacterial growth is often used as a general-purpose medium for the culture of fungal foliage pathogens. When fresh, recently infected tissues are cultured from marginal areas of infection, cultures should produce a consistent type of fungal growth. Fungal isolates should be transferred to a sterile petri dish with sterile medium to produce a single fungal isolate in pure culture. The growth of certain fungal pathogens is very distinctive in culture, aiding in identification of the pathogen. Conclusive evidence for fungal identification is the development of distinctive fungal spores or fruiting bodies. If tissue decay is advanced, several fungi may grow out in culture; each isolate should be examined to determine which ones are plant pathogens. In some cases, secondary pathogens or decay fungi may grow faster than the pathogen and the medium in the dish is overgrown by these undesirable fungi, preventing identification of the primary pathogen (Waller *et al.*, 1998; Shurtleff and Averre, 1997; Fox, 1993).

If fungus fails to grow from the cultured plant tissues, surface sterilization may have been too severe. It is often a good idea to prepare two to four culture dishes by using a range of surface sterilization times. The optimum sterilization time varies with the pathogen, the plant tissue type, and the secondary and decay organisms present. If a bacterial disease is suspected, a different method is used for isolation in culture. After surface sterilization of the tissue, a piece of the damaged tissue is placed into a sterile

plate and cut up or crushed in a drop of sterile filtered water. The macerated tissue remains in the water for 3 to 5 min, and then a small amount of water is streaked across a culture dish by a bacteriological transfer loop. A general-purpose medium for bacterial growth is tryptic soy agar, nutrient agar media, or plain agar. Most diagnostic labs will streak the bacteria in four quadrants in a prescribed manner so that the bacterial concentration is diluted by the time the last quadrant streak is streaked. The objective of the streak technique is to dilute the bacteria enough so that single cells will be separated in the last quadrant. The resulting colonies from single cells may be easily transferred to another culture dish, which is then a pure culture derived from a single bacterial cell. Bacteria are not easily identified as they do not produce microscopic structures that are diagnostic. Instead, bacteria are typically identified by specific physiological reactions or by specific molecular characteristics. Therefore, the isolation of bacteria in pure cultures is just the first step toward other procedures to identify the bacteria by genus and species (Waller *et al.*, 1998; Shurtleff and Averre, 1997; Fox, 1993).

Baiting

Using a bait to isolate a pathogen typically involves placing a piece of infected or damaged tissue into a healthy plant part where the specific pathogen will be stimulated to grow. Usually baits involve selective stimulation of growth for certain fungal pathogens. Carrot roots are baits for the fungal pathogen *Thielaviopsis basicola,* which causes black root rot of some plants. Green apples and green pears are used as baits for growth of the fungus *Phytophthora* . If culture methods are not available, successful baiting is an alternative strategy for isolating and identifying pathogens (Fox, 1993; Shurtleff and Averre, 1997; Waller *et al.*, 1998).

MODERN ASSAYS FOR PLANT PATHOGENS

Use of Serology Techniques (Ouchterlony and ELISA)

Serology, the study of immunological reactions, derives its name from *Serum* , which is blood fluid after all the blood cells are removed. There are several types of tests that involve immune reactions, that is, several tests that involve the reaction of antigens (substances foreign to the body, usually proteins) and antibodies (specific molecules produced by mammals in response to the presence of the foreign protein or substance). One of the first serology tests to be conducted was known as the Ouchterlony test, after the scientist who designed the test. In this test, the antigen-antibody reaction takes place in water agar within a petri dish. The antigen or foreign protein is placed into a well in the center of the plate. This antigen is tested against several known antibodies, which are individually placed into wells around the edge of the agar dish. The antigen and antibodies diffuse out of the wells and move through the agar medium. As these substances come in contact with each other, about midway from the center and edge of the plate, an arc of white precipitate is formed between the antigen and its antibody. There is no precipitate formed between the antigen and the other non reacting antibodies.

Today the most common serology test used by most diagnostic clinics/labs is known by the acronym ELISA, enzyme linked immunosorbent assay. The immune-reacting molecules (antigen and antibody) are adsorbed on to the wells of a plastic multiwell microtiter dish. One of the reacting antibodies is linked to an enzyme that allows for a

color reaction to indicate a positive test reaction. The type of ELISA may be direct or indirect. The direct test is often called a double-antibody sandwich and it is the shorter procedure of the two. The indirect ELISA is a longer procedure, but the longer protocol allows for a more reactive antibody-enzyme component to combine with the antigen. The indirect test is often considered to be more sensitive than the direct method. The wells of a multiwell plate are coated with a specific antibody(AB). After this AB is allowed to dry and be adsorbed onto the wells, the unknown antigen (usually the sap expressed from the infected tissues) is added to the test wells. At the same time control wells are prepared by adding sap expressed from a healthy plant of the same age, variety, and location as the infected test plant (a negative, healthy plant control); sap expressed from a plant known to contain the specific antigen or pathogen that is suspected to be present in the unknown test plant (a positive control); and buffer or water only (a negative control). The antibody (AB) - antigen (AG) reaction mixture is allowed to incubate for a period of time that varies depending on the specific antigen test. After the incubation time is complete, the wells (test and controls) are washed several times (usually six times) and then allowed to drain. If the AG reacted with the AB, the bound mixture of AB-AG remains attached to the test and positive control wells. If the test plant sap did not contain the specific antigen reactive with the added AB, then no binding took place and only the AB remains attached to the wells. The next addition to the wells is the AB preparation attached to an enzyme, which is usually peroxidase or alkaline phosphatase. The AB-enzyme (AB-E) will attach to those wells that contain the AG bound to the originally added AB. This three-component mixture of AB-AG-AB-E is allowed to incubate for the recommended period of time. After the incubation time is completed, the wells are again washed several times (usually six times) to remove any unbound AB-E from wells. Next, the substrate (S) for the enzyme (hydrogen peroxide or *p* -nitrophenylphosphate, respectively, for the aforementioned enzymes) is added and allowed to react with the mixture. A colour change indicates that the enzyme has bound to the substrate and is a positive test for the presence of the AB in question . If positive control wells and negative control wells react or not as they should, then the completed ELISA provides very valuable and specific information as to the identity of the pathogen causing the plant damage (Fox, 1993; Matthews, 1993; Schaad et al., 2001). ELISA results usually are ready in a matter of hours or after an overnight reaction, so the clients may obtain an indication of the cause of their problem in less than 24 h. This test procedure is very valuable for commercial growers where a rapid implementation of control measures could save the crop from widespread damage and economic loss.

Usually viruses are detected, through reaction on indicator plants and serology using ELISA. Double antibody sandwich (DAS), triple antibody sandwich (TAS) or indirect ELISA procedures are generally used for plant virus detection (Torrarce, 1992). The protocols are well documented. A simple pencillinase based ELISA has been standerdized for pototo viruses at CPRI, Simla (Singh and Khurana, 1994) ELISA with polyclonal antibodies for SVY (Khurana and Garg 1993), Tomato viruses TMV, TOMV, CMV, PVY, TYLCV, TEV, TSWV (Kooyman and Thompson, 1990; Kaminska 1996; Nava et. al. 1996; Nono Womdin et. al. 1996). Monoclonal antibodies specific to or detecting most isolates of PVY^e, PVY^N and PVY^o with or without little cross reaction to other strains have been reported (Ellis et. al. 1996; Mc Donald and Singh, 1996).

Moleculer techniques, using radioactive labelled complementary DNA or RNA probes are available for many potato viruses limited to advanced laboratories. Non radioactive probes based on digoxigenin are also available for effective testing of distant samples NASH (nuclic acid spot hybridisation) methods in which the virus particles are trapped on membranes. Specific primers have been developed for use in reverse transcription polymerase chain reaction (RT-PCR) protocols for a number of virus infecting potato. Potato Spindle Tuber Viroid can be detected in sap or nucleic acid samples using ^{32}P- or digoxigenin labelled DNA (Harris and James, 1987) or RNA probes are more sensitive than DNA probes. Return PAGE (polyaorylamide gel electrophoresis) with silver staining also provides sensitive detection (Singh and Boucher, 1987). Highly sensitive RT-PCR methods are also available for detection (Levy et. al. 1994; Shamloul *et al.* 1997) nucleic acid probes and PCR can be used for PVY detection and strain characterization (Baulcombe and Fernandez-Northcote, 1988; Barker et. al. 1993; Weidemann and Maejs, 1996). It is also possible to detect virus in aphids by duplex reverse trancription PCR (Singh *et al.* 1996).

Gas Chromatography of Bacterial Fatty Acids to Determine the Identity of Bacterial Pathogens

A gas chromatographic system has been designed to separate and quantify the fatty acids present in a bacterial preparation (Schaad *et al.*, 2001) and results in a fatty acid profile. Studies of the plant pathogenic bacteria and other bacteria have shown that fatty acid profiles may be characteristic and specific for individual bacterial genera, species, and pathotypes. The results of the gas chromatography are transmitted to a specially designed computer program where the fatty acid profile of the test bacterium is compared to a library of fatty acid profiles of other bacteria. Results are given as a similarity coefficient that expresses the degree or percentage of agreement between the test organism and the most similar bacterium in the library system. A very high coefficient, such as 0.925, indicates very good agreement and the probability that the identification is accurate to the genus, species, and pathotype taxa. A lower coefficient, such as 0.456, usually indicates the identification is accurate to the genus and species level. Not many diagnostic clinics perform bacterial fatty acid gas chromatography due to the expense of the equipment—some research labs will cooperate with clinics and perform identifications for diagnostic purposes. Before the analysis, the bacterial preparation in broth must be treated to disrupt or break the cell walls and release the fatty acids, which are then methylated so that they become volatile and move easily in the gas medium. The fatty acids are separated on size and identified by the rate of movement as compared to the movement rates for known fatty acids (Schaad *et al.*, 2001).

Gel Electrophoresis Used to Identify Specific Enzymes or Proteins of Specific Pathogens

Gel electrophoresis is a method of identifying proteins or enzymes by the rate at which they move through an electric field. The rate of their movement through the gel depends on their size and their electric charge. The rate of movement of a particular protein is compared to the rate of movement for known proteins. If production of a unique protein is specific for a specific pathogen or pathogen subspecies, the electrophoresis method can be used as a diagnostic method. This method was used to identify an enzyme specific to A2 mating types of metalaxyl-resistant *Phytophthora infestans* in the early 1990s. Gel

electrophoresis assisted pathologists in advising growers whether they should use metalaxyl or one of the newer, more expensive fungicides for late blight control.The analysis involved lysing the fungal cells, extracting. Identification of the protein bands in the gel involved a specific staining technique. The known proteins (positive controls) and negative controls must always beincluded with the test protein sample (Goodwin, 1995).

DNA Probe Molecular Methods to Determine the Identity of Pathogens

The most accurate method of organism identification is by DNA identification. Identification is always done by determining compatibility (or hybridization) of the test DNA single strand to the known DNA single strand. The "probe" refers to the marker attached to the known DNAsingle strand. The presence of the marker allows for visual identification of the double-stranded hybridized DNA. The attached probe might be radioactive P-32, biotin, a serology component of an ELISA reaction, or other markers. Basically the test involves extraction of the DNA, heating the DNA to cause separation of the double strands into single strands, addition of the known single-stranded DNA with attached probe, and cooling to facilitate reassembly (annealing) of the single-strands of DNA into double strands where the probe containing DNA is hybridized to the unknown DNA if the two DNA strands are compatible. If the unknown DNA is of the same identity as the known probe-connected DNA, then the probe will allow for detection of the double-stranded result. If the probe DNA is not compatible (does not hybridize) with the unknown DNA, then double strands will not form with the probe. The single-stranded probe DNA will be removed from the test solution. P-32 probes are detected by X-ray film and biotin is detected by a visible color reaction as is the case for an ELISA probe system (Duncan and Torrance, 1992; Matthews, 1993; Fox, 1993; Schaad et al., 2001) small amounts of a DNA sample so that small plant samples may be used for the DNA probe detection method (Schaad *et al.*, 2001).

Detection of *Spongospora subterranea* by ELISA Using Monoclonal Antibodies

Harrison *et al.* (1993) have developed an ELISA system, using polyclonal antiserum to resting spores, for the detection of tuber contamination (resting spores in soil, weakly detected). Soil contamination is currently assessed using bait plants like tomato. (numbers of plasmodia are estimated by microscopically inspection, a laborious process). *S. subterranea* is an obligate pathogen and can not be cultured and zoospores stage is the only free-living form of pathogen, so, zoospores can be used as the antigen for monoclonal antibody (MAbs) production. Production of MAbs by injection of mice with zoospore suspension by ELISA system can detect zoospore of pathogen. The 36 zoospore per well is essential for positive results. The other microorganisms other than target pathogen can not be react with this antibody or weakly react.

Development of Monoclonal Antibody-based Immunological Assays for the Detection of Live Propagules of *Rhizoctonia solani* in the Soil

Rizoctonia solani is a soil-borne pathogen that attacks a wide range of crop plants. Various techniques have been developed for the detection of *Rhizoctonia* species in the soil. these conventional methods are labour intensive, cumbersome, and require taxonomic expertise to differentiate species. Faster detection methods, such as immunoassays, that are specific and can easily be repeated, are provided to improve the precision by which

populations *of R. solani* can be detected in soil. (Thornton *et al.* 1994) Adams and Butler (1979) demonstrated that species-specific antibodies are present in polyclonal antisera raised against mycelial extracts of *R solani* The Diagnostic-ELISA is currently being used to quantify the decay *of R. solani* inoculums in the soil. Production *of* monoclonal antibodies, Mice were immunized using suspensions of lyophilized mycelium ELISA used for evaluating of reactions.

DNA Fingerprinting of the Potato Late Blight Fungus, Phytophthora Infestans

Drenth and Grovers (1994) in their publication "DNA fingerprinting of the Potato Late blight Fungus, *Phytophthora infestons* highlighted the importance of DNA fingerprinting in this most damaging pathogen. *P. infestans* is a very important pathogen belonging to Oomycetes and is known to contain two mating types A_1 and A_2 confined to Central Mexico and A_2 belonging to be prevalent all over world. With the preseuce of both mating types there is the possibility of sexual reproduction which result in the fomation of oosperes genetic diversity was observed as a result of sexual reproduction Maynard Smith (1971) explained that the effect of sexual reproduction can accelerate evolutionary adaptation and varialility in the population. Evolutionary adaptation is very difficult to measure but variability can be meascured by using diagnostic markers such as DNA fingerprint probes and RAPDs.

Markers available for *P. infestans*

(a) Biologically significant markers : Comprise maiting type, virulence and fungicide resistance. These type of markers are useful since they can be scored easily but with out the necessity of pure fugal culture. There is no known selection on mating type. Virulence and Fungicide Resistance are the characteristics that require the use of resistant potato cultivars or the application of fungicides such markes are not found successful, require a careful interpratation of data.

(b) Cytoplsmic markers are characterized by extrachromosomal inheretance leading to intact transmission for parent to progeny. Generally these markers are mitochondrial DNA and double stranded RNA (ds-RNA). Polymophism is very limited since they are transmitted without recombination from parent to progeny, cannot reflect diversity in sexual population.

(c) Neutral markers : These markers are not related to any biologically important characteristic. They are of two types – Allozyme and Polymorphic DNA.

Allozymes : Enzymes different in electrophoretic mobility as result of allelic diversity in a single gene are called as allozymes.

Polymorphic DNA : Most suitable markers suitable to conduct population genetic anlayses. DNA fingerprinting enables detection of multiple loci, is method which detects multiple loci. DNA fingerprint probe RG-57 has been isolated as a very useful probe for population genetic studies (Goodwin *et al.* 1992). Probe RG-57 allows virtually unambiguous identification of different isolates (Drenth and Grovers 1994).

There has been very rapid development of nucleic acid based technique. In particular, methods based on the polymerase chain reaction has taken center stage. While restriction fragment length polymorphism (RFLP) technique will continue to be used widely in research setting, very sensitive, very specific and rapid, these with levels of

sensitivity and specific approach the theoretical maxima of detection of one nucleolus of a specific genotype against a background of contaminating DNA(whether plant or fungal) that need differ at only one base in addition PCR assay can accurately quantify fungal infection .These bravura demonstration have shown unequivalently that PCR technique posses all the theoretical attributes of ideal detection system Many of the primers have been develop from the rDNA sequence which is very convenient because the ITS region seem species specific and yet they can easily be generated using conserved primer to the rDNA genes on by product of this is that unequivalent taxonomic information that is directly comparable with the fungal species is obtained. It is to be hoped that the sequence to these regions will be freely shared.

Even these methods have problems. These fall into two classes. Firstly there are technical problem with PCR amplification. These include false positive created by contaminating target DNA where the cure appear to be renewed laboratory hygiene and false negative cause primarily by inhibitors in DNA preparation of fungal or infected plant material, where the cure is partly the incorporation in suitable controls. There is still a clear need for rapid development in quick, clean and easy DNA preparation technique. Some of these technical problems may be easier to solve when the assay is based on the ligation chain reaction

The second problems concern the development of usable assay from PCR amplification. PCR generate at a specific ds DNA product, which is traditional detected by agarose gel electrophoresis. The information contain can reside in whether a band produced the size of the band or the sequence of the band as revealed either by restriction endonuclease digestion or even by sequencing for practical assay, one image that imagines that the production of a band will constitute the assay . In this case agarose gel electrophoresis would be too slow and cumbersome for routine, automated use. This requires use of a capture reagent which could be either (one of) the dNTPs or the primers. The second requirement is a detection reagent. The permulations are endless. These PCR detection methods are already available and being used for application in detection of pathogens.

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3

SYMPTOMATIC DIAGNOSIS

SOLONACEOUS CROPS

Potato (*Solanum tuberosum* L.)

FUNGAL

Late blight

Causal organism: *Phytophthora infestans* (Mont.) de Bary

Symptoms

Infection appears as pale green, irregular spots on the tips and margins of the leaves which, in moist weather, enlarge rapidly with central tissue turning necrotic and dark brown or black (Plate 1). Often, the spots have a purplish tinge. On the lower side of the leaves, a white mildew (cottony growth) ring forms around the dead areas. In dry weather, the water soaked areas dry up and turn brown. On stems and petioles light brown lesions develop, elongate and enlarge often encircling the stem/petiole. The whole vines may be killed and blackened and the disease spread rapidly killing the entire crop in a few days when the favourable conditions exist.

Tubers, in soil are readily infected by rain splashes from blighted foliage. Initially the tubers show a shallow, reddish brown dry rot that spreads irregularly from the surface through the flesh (Plate 2). Under humid and cloudy weather, the lesions on all plant parts show white cottony growth of fungus. Night temperature below dew point for at least four hours, cloudiness on the next day, minimum temperature 10° C and minimum rainfall during 24 hr of at least 0.1 mm are the principal factors governing occurence of late blight. The seed tubers and refuge piles in the temperate regions and cold stored tubers in subtropical regions serves as the primary source of inoculum.

Early blight

Causal organism: *Alternaria solani* (Ell. and Martin) Jones and Gro-ıt

Symptoms

Infection on the leaves appears in form of brown spots which may be angular, oval or circular. The spots may or may not have concentric rings. The rings are more prominent in large blotchy spots and give them a target board effect (Plate 3). The disease can be distinguished from late blight by the absence of white cottony fungal growth. When a spot appears on vein, a part of it gets necrosed. The fungus produces several toxins, including Alternaric acid in the host, which leads to yellowing of the leaves. Lesions on tubers are circular to irregular in shape, slightly sunken and often surrounded by a raised purple to dark brown border. Plants susceptible to biotic stresses are prone to early blight than healthy plants. The conidia and mycelium in the soil or in debris of infected plants serve as primary source of inoculum.

Black scurf

Causal organism : *Rhizoctonia solani* Kuhn

Tel: *Thanetophorus cucumeris* (Frank) Donk.

Symptoms

Infection developes on all parts of plant including growing tips of tubers. The fungus attacks young sprout through epidermis and produces dark brown lesions thereby killing the sprout before emergence, which result in patchy germination. Elongated reddish brown lesions develop on the stem at or below soil surface. The lesions enlarge and may girdle the stem. The affected plant lack vigour. When the girdling is complete, the foliage curls and turns pinkish to purplish. Aerial tubers are commonly seen. Towards the end of the crop season, the fungus produces sclerotia which are hard, small, dark brown to black resting bodies on the surface of mature tubers. These sclerotia when get deposited continuously form black encrustation on the tuber surface. In subtropical areas, seed tubers serve as main source of disease where as in temperate regions, the fungus survive in the soil through the year act as potential source of disease.

Potato wart

Causal organism: *Synchytrium endobioticum* (Schilberzky) Percival

Symptoms

All underground parts except root and basal part of stem near ground level exhibit symptoms. The abnormal growth activity starts on buds, under ground stem, stolon and tubers which leads to development of warts. The outgrowth is spherical, green or greenish white in colour if expose above and it gives cream colour when underground. In advanced stages, the warts are darker in colour, sometimes black. The wart consists of distorted, proliferated branched structure grown together into a mass of hyperplastic tissue. The main survival structures of this pathogen are resting spores present in host debris or soil.

Charcoal rot

Causal organism: *Macrophomina phaseolina* (Tassi) Goid.

Symptoms

The fungus may grow from infected seed tuber up the stem to the soil surface and kill the plant. A soft, dark coloured shallow rot develops on soil surface and lower stem area. Secondary organisms frequently follow primary infection by charcoal rot pathogen. The fungus enters tubers through stolons, eyes, lenticels and injuries. Initial symptoms appear in the form of black spots (2-8 mm in diameter). The skin of the tubers remains unaffected but the tuber flesh gets blackened to a depth of 2 to 5 mm. In dry rot, black sunken areas develop on the tuber which turn into cavities underneath the skin. The cavities are filled with fungus mycelium and sclerotia. In advanced stage, secondary pathogens attack the tuber which ultimately is reduced to a foul smelling wet rotting mass. Both tubers and soil may serve as primary source of disease.

Fusarium wilt and dry rot

Causal organism: ***Fusarium oxysporum*** **Schlechtend ex Fn.**

F. solani **(mart) Sacc.f.sp.** ***eumatii*** **(Carpenta) Snyder and Hans**

F. muconeva **(Fr. Ex Fr.) Sacc.**

F. avenaccum **(Fr. Ex Fr.) Sacc.**

F. acuminatum **Ellis and everh.**

Symptoms

The characteristic symptoms include wilt, stem rot and damping off of seedlings. On tuber, pathogen produces spots, necrosis, dry rot and seed piece decay. Both stems and tubers at stolon end show vascular browning. In some cases, wilting may be accompanied by rotting of stem base. Stem rot leads to yellowing, rotting and rosetting of leaves. Tubers and stolons may also develop brown lesions. It may cause damping off of seedlings if planted early in the season when temperature is high. *Fusarium acuminatum* causes rotting of the stems that may extend up to the growing tip. Infected tubers and soil are primary source of inoculum.

Powdery scab

Causal organism: ***Spongospora subterranean*** **(Wallr.) Lagarh.**

Symptoms

It appears as pimple like spots which are circular, smooth and light brown present on the surface of leaf and ultimately rupture, exposing a cavity containing a brown powdery mass of spore balls. The cavity is surrounded by the remanents of the ruptured periderm. The spots may coalesce. Occasionally warty purtuberances are produced in some cultivars. Sometimes, the affected tubers show destruction of the flesh due to renewed activity of the pathogen below the primary pustules resulting in hollowed out patches. These types of lesions are called cankers. Powdery scab pustules are filled with mass of fungal spore ball. Sometimes small galls occur on the roots of affected plants. The fungus overwinters through spores in soil and on infected seed tubers.

BACTERIAL

Bacterial wilt/Brown rot

Causal organism: ***Ralstonia solancearum*** **(Yabuuci** ***et al*****)**

Symptoms

The characterstic symptoms of the disease are stunting, yellowing of lower foliage, sudden wilting and finally collapse of the entire plant. The brown rot refers to the browning of the xylem in the vascular bundles. The browning is often visible from the surface of the infected stem as dark patches or streaks. The name ring disease is derived from the fact that a brown ring in the tuber due to discoloration of the vascular bundles. The skin of the infected tubers is often discoloured. In severely affected tubers, the eye buds are blackened. If the infected stems or tubers are cut across and squeezed, greyish white bacterial ooze comes out of the vascular ring. Infected soil and infected tubers are two distinct source of inoculum.

Black leg and soft rot

Causal organism: ***Erwinia caratovora*** **f.sp** ***atroseptica*** **(van Hall) Dye**

Erwinia caratovora **f.sp** ***caratovora*** **(Jones) Bergey** ***et.al***

Symptoms

Stem bases of diseased plants typically show an inky-black to light-brown decay that originates from the seed piece and can extend up the stem from less than an inch to more than two feet. Leaves of infected plants tend to roll upward at the margins, become yellow, wilt, and often die. Aerial stem rot (also called bacterial stem rot or aerial blackleg) is initiated by soft-rot bacteria from sources external to the seed piece. Stem infection can occur through wounds or through natural openings such as leaf scars which enlarge into a soft, mushy rot that causes entire stems to wilt and die. Potato tubers with soft rot have tissues that are very soft, watery and diseased tissue is cream to tan coloured, often has a black border separating diseased from healthy areas. Soft-rot decay is generally odorless in early stages but later a foul odour and a stringy or slimy decay usually develop as secondary decay, bacteria invade infected tissues. Pathogen survives in the rotted tubers.

Scab of potato

Causal organism: ***Streptomyces scabies*** **(Thaxter) Waksman and Henrici**

Symptoms

Shallow scab symptoms are characterized as superficial roughened areas, slightly raised or sometime sunken below the level of healthy skin. (Plate 4) The lesion are corky tissue arise from abnormal proliferation of tuber periderm when tuber is exposed to pathogen. Individual scab lesions are circular but may coalesce into large scabby areas. In deep pitted scab, lesion are 1-3 mm or more in depth and darker than shallow scab. Insects may be involved in creating deep-pitted lesions. The term "common scab" generally refers to the response of the disease to soil pH. Pathogen is seed and soil borne in nature.

VIRAL

Leaf roll

Causal organism: Potato leaf roll virus

Symptoms

The rolling of leaves is characterized by curling of leaflet margins inward thus forming a trough in which the midrib is at bottom (Plate 5). In secondary infection, this rolling of leaves starts in lower leaves and progresses upward through out the plant. The

rolled leaflets are stiff and rigid. They are thick and leathery, sometimes with pink margin. Internal necrosis is a symptom of tubers. In nature transmission of virus occurs through infected tubers and aphid vectors. *Myzus persicae* is the main aphid vector.

Potato mosaic

Mild mosaic: Potato virus X

Major symptoms is interveinal mosaic, sometimes little dwarfing in potato.

Super mild mosaic

Causal organism: Potato virus A

It is either shining or roughness of leaf surface but in case even without any symptoms depending on the cultivar.

Vein banding severe mosaic

Causal organism: Potato virus Y

Mild to severe mottle and streak or leaf drop streak with necrosis along the veins of underside of leaflets. The leaves become completely necrotic but remain hanging. *Myzus persicae* is the most efficient vector.

Rugose mosaic

Causal organism: Potato virus X, Potato virus Y

The foliage is not only mottled but is also severely wrinkled, puckered and markedly reduces in size. The leaflet margins are rolled downward and entire plant is severely dwarf. The lower leaves generally have black necrotic vein. *Myzus persicae* is capable of efficiently transmitting potato virus.

Crinkle of potato

Causal organism: Potato crinkle virus

It is characterized by yellowish patches on the foliage, which are bigger and more prominent. The colour becomes more pronounced and is accompanied by rust brown spot beginning near the tip of the leaves. The foliage is brittle and easily injured.

Spindle tuber of potato

Causal organism: Viroid

Symptoms

Symptoms are often not visible during the first season but become progressively more severe in the following generations. Infected plants are stunted and have an upright or erect appearance. Tuber symptoms are more obvious but do take several generations to appear. Affected tubers are small and deformed becoming cylindrical and elongate ('spindle'). They are often pointed and can show growth cracking on larger tubers. Eyes will often become more prominent and sprouting is slower than with healthy tubers.

MYCOPLASMAL

Purple top roll

Characterized by rolling and purple or pink colouration of the basal part of leaflets

of the top leaves along with stunting, chlorosis, profuse auxillary shoots with aerial tubers and swelling of nodes. There is no wilting of infected plants and no necrosis of the tubers. Infected tubers seem to be the important source of perennation and transmission.

Marginal flavescence

Symptoms are chlorosis on the margins of upper leaves. The chlorosis intensifies, leaf blade become thick, rough and puckered. Growth is stunted because of short internodes with small leaves having narrow leaflets partly overlapping each other. Infected plants produce few small tubers close to stem ie on short stolon. Tubers carry the pathogen and serve as source of primary inoculum.

Witch broom

Extreme stunting of plant and numerous filamentous stems with simple leaves. Very small tubers are formed by affected plant. The pathogen is transmitted by leafhopper and perennates through tubers.

NEMATODE

Golden nematode or cyst nematodes

Causal organism: ***Globodera rostochienensis***

Symptoms

The plant appear as suffering from poor nutrition. At hotter part of the day, plant show temporary wilting. Typical symptoms are stunting of growth with unhealthy foliage. Premature yellowing, the development of root system get poor reduce the size and number of tuber. Main source of survival of nematode is the cyst.

NON PARASITIC DISEASE

Black heart of potato

It is an important storage, transit and market disease of potatoes as a result of poor oxygen supply and usually occurs in tubers stored in poorly ventilated rooms closely packed conditions. Dark grey to purplish or inky black discoloration occurs in the central tissues of the tuber. In advanced stages, the affected tissues may dry out and separate thus forming cavities.

Tomato (*Lycopersicon esculentum* Mill)

FUNGAL

Damping off

Causal organism: ***Pythium aphanidermatum*** **(Edson.) Fitep.**

P. butleri **Subram**

Symptoms

Symptoms of disease occur in two phases i.e. pre-emergence and post-emergence damping off. In the former, there is failure of seedling emergence from the soil either due to seed rots or killing of young seedlings before their emergence from the soil, hence resulting in patchy appearance of seedlings stands in the nursery in early stages of growth.

In case of post emergence damping off, the disease outbreak is characterized by toppling over of infected seedlings at any time after their emergence from the soil. The pathogen is either seed or soilborne or both.

Fusarium wilt

Causal organism: *Fusarium oxysporum* Schlechtend ex Fr. f. sp *lycopersici*

Symptoms

Clearing of veinlets and drooping of petioles of young plants characterize the disease. Lower leaves show yellowing and die prematurely. Later, the whole plant wilts and dies prematurely. After the disease has advanced for a few weeks, browning of the vascular system can be seen in a cross section of the lower stem or by removing stem tissue near the collar region with a knife (Plate 6). Fusarium wilt of tomato crop is emerging as a major disease in those parts of world where soil temperature remains high during the period of its cultivation. The fungus is soilborne and persists in soil for many years.

Southern blight

Causal organism: *Sclerotium rolfsii* Sacc

Symptoms

The first symptom is drooping of leaves. On the stems, a brown, dry rot develops near the soil line. White fungal growth with brown mustard seed-sized sclerotia may be visible. The stem lesion develops rapidly, girdling the stem and resulting in a sudden and permanent wilt of all aboveground parts. Frequently, a white fungal mat covers the lesions. The fungus can also attack fruits where they touch the soil. The fungus can survive for years in soil and plant debris. Moist conditions and high temperatures favor it.

Late blight

Causal organism: *Phytophthora infestans* (Mont.) de Bary

Symptoms

On leaves, it appears as pale, green, irregular spots on the tips and margins which moist weather enlarge rapidly with central tissue turning necrotic and dark brown or black. On the lower surface of the leaves, a white downy growth of the fungus appears around the dead areas. In dry weather, the growth of the fungus is checked and the watersoaked areas dry up and turn brown. Brown streaks develop along the stems. On green fruits olivaceous greasy spots appear which gradually cover the entire fruit. Initially, the tissue remains firm with varying depths of discoloured tissue below the skin but when blight is followed by soft rot, the fruit soon disintegrates. The fungus is soil borne and mostly survives in infected potato seed tubers, cull piles, neighbouring potato field, infected plant debris and other host plant.

Buckeye rot

Causal organism: *Phytophthora parasitica* Breda de Hann

Symptoms

The first fruit symptoms appear as brownish spots, often at the point of contact between the fruit and the soil. As the spots enlarge, dark, concentric rings can be seen.

Lesions of buckeye rot resemble those of late blight, except that the former remain firm and smooth, whereas late blight lesions become rough and are slightly sunken at the margins. Under moist conditions, a white, cottony fungal growth appears on the buckeye rot lesions (Plate 7). With time, the entire fruit will rot. The fungus does not affect the foliage. The fungus survives in the soil in the form of chlamydospores and oospore and in infected seed and is spread by surface water and rain.

Powdery mildew

Causal organism: *Leveillula taurica* (Lev.) Arnaud

Symptoms

The symptoms are characterized by a white talcum like covering on the lower surface of the leaves while the corresponding upper surface turns yellow. The infected leaves shed prematurely. Dry weather condition coupled with low humidity is favourable for disease initiation and spread. The pathogen perennates on the weed host.

Alternaria leaf spot

Causal organism: *Alternaria solani* Sorauer

Symptoms

The fungus can affect seedlings but generally is a problem of older plants. Lowest leaves are attacked first and then the disease progresses upwards. Dark brown spots with concentric rings develop on the leaves, which give target board effect, the most characteristic symptom of the disease (Plate 8). In several attacks, affected leaves shrivel and fall down prematurely resulting in early defoliation. Fungi survive in diseased plant debris.

Septoria leaf spot

Causal organism: *Septoria lycopersici* Speg.

Symptoms

The disease can be diagnosed by observing numerous small, water-soaked spots with dark borders surrounding a light grey center appear on the lower surface of the older leaves. Black specks, which are spore-producing bodies, can be seen in the center of the spots. Severely spotted leaves turn yellow, die and fall off the plant. Defoliation weakens the plant, reduces the size and quality of the fruit and exposes the fruit to sunscald. The fungus can overwinter on crop residue from previous crops, decaying vegetation and some wild hosts related to tomato. The pathogen perennates in diseased plant debris in the field and on or in the seed.

Leaf mold

Causal organism: *Cladosporium fulvum* Cooke

Symptoms

The initial symptoms are pale green or yellowish spot on the upper leaf surface which enlarge and turn a distinctive yellow. Under humid conditions, the spots on the lower leaf surfaces become covered with a grey, velvety growth of the spores. When infection is severe, the spots coalesce and the foliage is killed. The fungus attacks stems, blossoms and fruits. Green and mature fruit can have a black, leathery rot on the stem end. The fungus survives on crop residue and in the soil. Seeds can be contaminated.

The fungus is dependent on high relative humidity and high temperature for disease development.

BACTERIAL

Bacterial spot

Causal organism: *Xanthomonas vesicatoria* (ex. Doidge)

Symptoms

The symptoms are characterized by numerous small, angular to irregular, water-soaked spot on the leaves and slightly raised to scabby spots on the fruits. The leaf spots may have a yellow halo. The centers dry out and frequently tear. The bacteria survive on volunteer tomato plants and on infected plant debris (Plate 9). Moist weather and splattering rains are conducive to disease development. Infection of leaves occurs through natural openings. Infection of fruits must occur through insect punctures or other mechanical injury. The pathogen is mainly seed borne and also perennates in plant debris.

Bacterial wilt

Causal organism: *Ralstonia solanacearum* (Smith) Yabuuchi *et al*

Symptoms

The disease can be identified by sudden drooping of the leaves, without yellowing often accompanied by rotting of the stem (Plate 10). This bacterium survives in the soil for long periods mainly confined to vascular region which later on spreads to cortex and pith causing yellow brown discoloration of tissues. The bacteria multiply rapidly inside the water-conducting tissue of the plant, filling it with slime. This results in a rapid wilt of the plant, while the leaves stay green. If an infected stem is cut crosswise, it will look brown and tiny drops of yellowish ooze may be visible.

Scab of tomato

Causal organism: *Streptomyces scabies* (Thaxter) Waksman and Henrici

Symptoms

Overall plants become stunted and due to a shortening of the internode, it show 'bunchy top' where the foliage becomes crowded, spindly shoots can sometimes be formed. Leaf symptoms include yellowing and purpling, along with considerable leaf distortion including downward curling of the leaflets ('epinasty'), curling and twisting. Severe necrosis along the veins develops later in the lower and middle leaves and these will eventually die. The younger leaves at the top of the plant will remain but are reduced in size. The fruit becomes small and hard and can turn dark green. Overall yields are significantly reduced. Soil and infected tubers are source of primary inoculum.

VIRAL

Tomato spotted wilt

Causal organism: Groundnut Bud Nurosis Virus

Virus infection appears as light and dark green mottling of the leaves. Plants are stunted, bronzed, spotted and have prominent purple veins. Fruits may have yellow spots.

Tobacco mosaic virus (TMV)

It causes mottling of older leaves and may cause malformation of leaflets which may become shoe string-like in shape. Viruses are highly infectious and readily transmitted by any means that introduces even a minute amount of sap from infected into healthy plants.

NON PARASITIC

Blossom end rot

Symptoms are water-soaked spots on the blossom end of the fruit. These spots enlarge and become black. Secondary infection by decay-causing organisms usually follows. The cause of this disorder is a calcium deficiency in the developing fruit. Extreme fluctuations in moisture, root pruning and excessive nitrogen fertilization can also enhance blossom end rot.

Growth cracks

Tomato cracks when environmental conditions ie drought followed by heavy rain or watering encourage rapid growth during ripening. Some cracks may be deep, allowing decay organisms to enter the fruit and cause fruit rot.

Sunscald

It occurs when tomatoes are exposed to the direct rays of the sun during hot weather and commonly observed on green fruit. Decay causing fungi frequently invade the damaged tissue. (Plate 12)

Poor fruit set

- Extreme temperatures: The blossoms drop off without setting fruit when temperatures are below 12.5° C or above 32° C for extended periods. Use Sunmaster Hybrid for heat-tolerance.
- Dry soil: Blossoms dry and fall when the plants do not receive enough water.
- Shading: Few blossoms are produced when the plants receive less than six hours of sun a day.
- Excessive nitrogen: High nitrogen levels in the soil promote leaf growth at the expense of blossom and fruit formation. Correct the nitrogen imbalance with superphosphate or 0-10-10 fertilizers.

Brinjal (*Solanum melongena* L.)

FUNGAL

Damping off

Causal organism: *Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp.

Symptoms

The disease causes severe damage in the nursery. High moisture and moderate temperature along with high humidity especially in the rainy season leads to the development of the disease. Two types of symptoms are observed Pre-emergence damping-off: The pre-emergence damping off results in seed and seedling rot before these emerge

out of the soil. Post-emergence damping-off: The post-emergence damping off phase is characterized by infection of the young, juvenile tissues of the collar at the ground level. The infected tissues become soft and become water soaked. The collar portion rots and ultimately the seedlings collapse and die. The fungus is soilborne in nature.

Sclerotinia blight

Causal organism: ***Sclerotinia sclerotiorum*** **(Lib) de Bary**

Symptom

The infection is mainly on the stems and branches. At the point of infection, a dry discoloured spot develops which gradually girdles the stem and also progresses up and down. In case of severe infection, wilting of plant take place. The entire plant wilt at the base of infection. Brown to black sclerotia may develop on the stem in the pith portion. When fruits are attacked, there is rotting of flesh and in rotting tissue several sclerotia may be seen. The fungus perpetuates inform of sclerotia in the soil or plant debris.

Phomopsis blight and fruit rot

Causal organism: ***Phomopsis vexans*** **(Sacc & Syd)**

Tel: ***Diaporthe vexan*** **Gratz**

Symptoms

The fungus infects the seedlings in the nursery causing damping off symptoms. When the leaves are infected small circular spots appear which become grey to brown with irregular blackish margins. Petiole and stem causing blighting of affected portion of the plant. Symptoms on the infected fruits appear as minute, sunken dull and dusky spots which later merge to form rotten areas. (Plate 13) The flesh of severely infected fruits rots. The fungus perpetuates in soil and lives on affected tissue. It is also seed borne.

Leaf spot

Causal organism: ***Cercospora melongenae*** **Welles**

Symptoms

The disease symptoms are characterized by chlorotic lesion, angular to irregular in shape, later turning greyish-brown with profuse sporulation at the center of spot as black dots. Severely infected leaves drop off prematurally resulting in reduction in yield. The fungi are soil borne and also seed borne when fruit rot occurs. Diseases crop debris in soil forms the chief source of primary inoculum. Severely infected leaves drop off prematurely, resulting in reduced fruit yield.

Alternaria leaf spots

Causal organism: ***Alternaria melongenae*** **Rang and Samb.**

Symptoms

The disease causes characteristic leaf spots with concentric rings. The spots are mostly irregular and coalesce to cover large areas of the leaf blade. Severely affected leaves drop off. The symptoms on the affected fruits are in the form of large deep-seated spots. The infected fruits turn yellow and drop off prematurely. The fungi are soil borne and

seen borne when fruit rot occurs. Diseased crop debris in soil forms the chief source of primary inoculum.

Verticillium wilt

Causal organism: *Verticilium dahliae* Kleb

Symptoms

The disease attacks the young plants as well as mature plants. The infected young plants show dwarfing and stunting due to the shortening of the internodes. Such plants do not flower and fruit. Infection after the flowering stage results in development of distorted floral buds and fruits. The affected fruits finally drop off. The infected leaves show the presence of irregularly scattered necrotic pale yellow spots over the leaf lamina. Later on, these spots coalesce resulting in complete wilting of the leaves. The roots of the affected plants are split open longitudinally, a characteristic dark brown discoloration if the xylem vessels is observed. The fungus is seed borne and primary inoculum usually starts from the soil.

BACTERIAL

Bacterial wilt

Causal organism: *Pseudomonas solancearum* E.F.Smith

Symptoms

The characteristic symptoms of the disease are wilting of the foliage followed by collapse of the entire plant. The wilting is characterized by gradual, sometimes sudden, yellowing, withering and drying of the entire plant or some of its branches. The vascular system becomes brown.

Little leaf of brinjal

Causal organism: Mycoplasma

Symptoms

The disease is transmitted by leafhopper (*Cestius* (*Hishimonus*) *phycitis* and *Amrasca biguttula*). The leaves of the infected plants in the early stages are light yellow in colour. The leaves show a reduction in size and are malformed. Disease affected plant are generally shorter bearing a large number of branches, roots and leaves than healthy plants. The petioles get shorter considerably, many buds appear in the axil of leaves and internodes get shortened thus giving the plants a bushy appearance. Flower parts are deformed leading the plants to be sterile. Infected plants do not bear any fruit. However, if any fruit is formed it becomes hard and tough and fails to mature.

Mosaic

Causal organism: Potato Virus X

Symptoms

This is a viral disease caused by potato virus Y and transmitted by aphids (*Aphis gossypi* and *Myzus persicae*). The important symptoms of the disease are mosaic, mottling of the leaves and stunting of plants. The leaves of infected plants are deformed, small and leathery. Plants show a stunted growth when infected in the early stages.

Root knot nematodes

Causal organism: ***Meloidogyne incognita***

Symptoms

Sedentary endoparasitic cause the root knot disease. Several infested are plants stunted, frequently wilt during hot days despite the presence of moisture, Plant in general sickly in appearance with characteristics galls in roots, infested tuber uneven with the surface showing numerous pimple like galls marking them unfit for consumption. Root knot nematode is microscopic worms that live in the soil and in plant roots. Affected plants are usually stunted, discoloured and may die. Knots or galls develop on the roots.

Chilli (*Capsicum annum* L.)

FUNGAL

Damping off

Causal organism: ***Pythium aphanidermatum*** **(Edson) Fitzp**

Symptoms

The seed may rot or the seedling may be killed showing pre emergance damping off. The fungi may affect the stem of young seedling, finally girdling of the stem takes place. The effected seedling may topple down. In nursery the disease may begin in patches and within few days the entire seedlings may be killed.

Fruit-rot and dieback or anthracnose

Causal organism: ***Collectotrichum capsici*** **(Syd.) butler & Bisby**

Tel: ***Glomerella cingulata*** **(Stonem) Spauld & Schrenk**

Symptoms

Disease appears in the month of October-November at the time of flowering. Individual flowers get infected and dry up. The disease symptoms are observed in two phases i.e. on twig as die back and on ripe fruit as fruit rot. The infection gradually spreads to the stem also. In the affected stem, the barks first turn brownish and then turn to shinny white in long and narrow strips containing several black dots like fructifications. Affected twigs get with red and dry up from tip downward and the disease spreads to the fruits also. (Plate 14) Circular to oval black spots occur on the ripe pods. Severally affected pods turn straw coloured instead of normal red, shrival and dry up. The pathogen overwinters in crop debris and seeds of infected fruits.

Fusarium wilt

Causal organism: ***Fusarium annum*** **Leonian**

Symptoms

It is characterized as upward and inward rolling of leaves and wilting of plant. The leaves turn yellow and die. There is cortical decay of collar and the roots. The fungus perpetuates in the soil.

Stem rot

Causal organism: ***Sclerotium rolfsii*** **Sacc**

Symptoms

Sudden wilt of individual plants scattered around the field. Initially there is foliar discolouration but later the leaves may turn yellow. The cortical tissues at the base of the stem turn brown and decayed above and below soil line. Sclerotia about size of mustard seed are tan to brown in colour when mature are produced in the mycelium mat. Sclerotia are the principal mean of its long-term survival in absence of the host or suitable substrate.

Grey mold

Causal organism: ***Botrytis cinerea*** **Pers ex Fr**

Symptoms

Disease is characterized as sudden collapse of succulent tissues such as young leaves and flower. The lesion expands rapidly forming irregular shaped watersoaked areas that result in the death of seedling and older branches. Fruits lesion begin as soft olive-green spot that may enlarge to cover the whole of fruit surface. The pathogen overwinters in plant debris and soil.

Cercospora leaf spot or Frogeye leaf spot

Causal organism: ***Cercospora capsici*** **Heald & Wolf**

Symptoms

Small necrotic lesion develops on the surface of leaves which later coalesce giving an irregular and blighted appearance. These lesions are typically brown, circular with small light grey center and brown margins (Plate 15). They may enlarge to one or more min in diameter. Center may fall out giving shot holes. Lesion elliptical in shape also appears on the stem, petiole and peduncle with light grey centers and dark border. The fungus subsists on the seed and in association with crop residues.

Powdery mildew

Causal organism: ***Oidiopsis taurica***

Tel: ***Leveillula taurica*** **(Lev)**

Symptoms

This disease occurs in December -February, Whitish powdery patches are seen on the lower surface of the leaves. The first symptoms are noticed on older leaves which progress to younger leaves. Chlorotic spots becoming necrotic are seen on upper surface of leaves. The under surface corresponding to these lesion is covered with white to grey powdery growth of fungus. In advanced stages, drop-of leaves takes place. F urther flower production is ceased. Cultivated host and wild host ensure the survival of fungus.

BACTERIAL

Bacterial leaf spot

Causal organism: ***Xanthomonos vesicatoria*** **(ex Doidge)**

Symptoms

It occurs in October to December months. In the beginning of disease small brown spots are seen on leaves, which turn into greyish or black spots on fruits also (Plate 16). In severe cases, the affected leaves turn yellow and drop-off. Stem infection results in wilting of tender branches and twigs. The pathogen persists in crop debris and infected seeds.

Bacterial wilt

Causal organism: *Ralstonia solancearum* (Smith) Yabuuchi *et al*

Symptoms

The characterstic symptoms of the disease are stunting, yellowing of lower foliage, sudden wilting and finally collapse of the entire plant and browning of the xylem in the vascular bundles. The browning is often visible from the surface of the infected stem as dark patches or streaks. The skin of the infected fruit is often discoloured. If the infected stems or tubers are cut across and squeezed, greyish white bacterial ooze comes out of the vascular ring.

Mosaic

Causal organism: Mosaic virus

Symptoms

Mosaic virus diseases also cause considerable damage to chilli crop. Mosaic disease exhibits itself as vein clearing of the younger leaves followed by severe mottling with patches of light and dark green scattered all over the leaf surface (Plate 17). Other important symptoms are leaf distortions, curling, marginal rolling of leaves. The plants become stunted and flower production is ceased.

Leaf curl

Causal organism: Leaf curl virus

Symptoms

Curling of leaves, downwards, their small size, shorted internodes, stunting of plant growth giving a witch's broom appearance. The affected plant stop bearing of fruits. The leaves become pale yellow. The virus is transmitted by white fly *Bemisia tabacci.*

Root knot nematodes

Causal organism: *Meloidogyne incognita*

Symptoms

Sedentary endoparasitic causing the root knot disease and severally infested plants become stunted, frequently wilt during hot days despite the presence of moisture, plant in general sickly in appearance with characteristics galls in roots, infested tuber uneven with the surface showing numerous pimple -like galls marking them unfit for consumption. Root knot nematode is microscopic worms that live in the soil and in plant roots. Affected plants are usually stunted, discolored and may die. Knots or galls develop on the roots.

Cucurbitaceous Crops

Pumpkin (*Cucurbita moschanta* Dutch-ex Poir)

Ash gourd (*Benincasa hispida* Cogn)

Summer squash (*Cucurbita pepo* L.)

Bitter gourd (*Momordica chrantia* L.)

Cucumber (*Cucumis sativus* L.)

Snake gourd (*Trichosanthes anguina* L.)

Ridge gourd (*Luffa acutangula* Rouxb.)

Bottle gourd (*Laginaria siceraria* (Mol.) Standl.)

Watermelon (*Citrullus vulgaris* Schrad. Ex. Eckl. & Zeyh.)

Pointed gourd (*Trichosanthes dioica* Roxb.)

Muskmelon (*Cucumis melo* L.)

Rounded gourd (*Citrullus vulgaris* var. *fistulosus* Duth & Full)

FUNGAL

Fruit rot

Causal organism: ***Pythium aphanidermatum*** **(Edson) Fitzp**
P. debaryanum **Hesse.**
P. butleri **Subram**

Symptoms

Symptoms develop on the surface in contact with the soil initially as watersoaked lesions, which transform into watery soft rot and eventually the fruits rot. Under humid conditions white cottony mycelial growth cover the fruits, also named as cottony leak. Secondary bacterial invasions result in foul smell. In cucurbits the decay frequently starts at blossom end. Incipient infection initiated in the fields leads to total rot of the infected and neighbouring fruits in transit and storage. The fungus is soil inhabitant living in precolonized tissues of the host or mostly as oospore. Under suitable conditions, these oospores germinate and cause infection. (Plate 18 and 19)

Fusarium wilt

Causal organism: ***Fusarium oxysporum*** **Schlechtend ex fsp *cucumerinum* Owen**
Fusarium oxysporum **fsp *meloni* Snyder & Hans**
Fusarium oxysporum **fsp *niveum* (E F Smith)**
Fusarium oxysporum **fsp *lagenariae* Matuo & Yamamoto**

Symptoms

The symptoms are expressed maximum at the flowering and fruiting stage and a loss in turgor and shrinkage below the collar region was notice at first leaf stage finally plant die. Sometimes typical flaccidity of leaves may be accompanied by yellowing and/ or marginal necrosis (only in bottle gourd). A long narrow brown streak may develop on one side of the stem near the soil level extending upward. The diseased plants may

bear a large number of fruits, which ultimately shrivel before attaining full size. A very striking underground symptom is replacement of taproot by a number of lateral roots, which try to makeup for the clogged xylem vessels of the infected taproot. Sometimes the plants may not show wilting but remain severely stunted do not bear any fruit. The pathogen is seed borne and soil borne.

Fusarium root rot

Causal organism: ***Fusarium solani* fsp *cucurbitae* Snyder and Hansen**
Tel: *Hyphomyces solani* Reinke and Borth

Symptoms

The infected plant show sudden wilting during the mild season. The disease can distinguish from the vascular wilt by the dark brown cortical soft decay at the base of the stem. The underground parts are found disintegrated. In humid weather, the stem base may be seen covered with fungal growth. The fungus is seed borne and survives in the form of perithecia.

Anthracnose

Causal organism: *Colletotrichum orbiculare* (Berk & Mont) Arx.

Symptoms

The disease develops on the foliage in the form of small, yellow, water-soaked spots. These affected areas enlarge, turn brown and shatter, or occasionally the entire leaf dies. When the petioles of cucurbits are infected, complete defoliation may result or the entire vine may be killed. Symptoms on infected fruit are sunken, black, circular spots. When moisture is present, the sunken circular spots are lined with masses of salmon-colored spores. (Plate 20 and 21) Usually these sunken spots do not penetrate deep into the fruit but damaged areas provide an entrance for soft rot organisms. The pathogen can survive in infected plant debris and in and on the seed. The disease is favored by warm, moist environmental conditions. The spore masses formed on the lesions are carried by rain splash and irrigation water leading to secondary infection. The spores may be carried by beetles and other insects.

Cercospora leaf spot

Causal organism: ***Cercospora citrullina* Cooke**
***Cercospora trichosanthes* var *anguinae* Rang & Chand**
***Cercospora memordicae* Mc Rae**
***Cercospora laginaria* Rang and Chand**
Cercospora cucurbiticola

Symptoms

Appearance of water soaked areas on the leaf lamina. These spot enlarge rapidly to become circular to irregular spot with pale brown tan or white centers and wide purple to almost black margin. Many spots may coalesce to form blotches. The leaf may dry and finally die. The fungus perpetuate on the perennial weeds and on the diseased crop debris.

Scab

Causal organism: ***Cladosporium cucumerinum***

Symptoms

The first symptom of disease is water-soaked spots on the foliage. These spots are numerous on the leaf. As the disease progresses, affected tissues turn brown, then white and finally die. The dead tissue may tear away from healthy tissue, giving the leaf a ragged appearance. Small, sunken, circular spots develop on infected fruit and a sticky substance is exuded. As the disease progresses, the infected areas continue to enlarge and blacken. Dark green spores are produced in these infected areas of the fruit and are easily disseminated to healthy plants. The fungus probably overwinters in old, infected plant debris and on the seed. Disease development is favored by cool, moist weather.

Alternaria blight

Causal organism: ***Alternaria cucumerina***

Symptoms

The first symptom of disease usually occurs on the foliage during the middle of the growing season. The disease spreads rapidly on the leaves, resulting in small, yellow spots, which enlarge to form concentric rings on the upper leaf surface. Muskmelons are much more susceptible than other cucurbits to Alternaria and often the vines will be almost completely defoliated. The pathogen also may cause fruit injury. The fungus can be carried in and on the seed. It can also survive in the winter season in diseased crop debris and cucurbit weeds. Warm and wet weather favors disease development.

Powdery mildew

Causal organism: ***Erysiphe cichoracearum*** **DC.**
Sphaerotheca fuliginea **(Schlecht ex Fr.) Poll.**
Leveillula taurica **(Lev.) Arnaud**

Symptoms

The disease appears as small powdery spots on the lower and then on the upper surface of the foliage. Spots are towards rusty brown in case of *Sphaerotheca* infection and pure white when due to *Erysiphe* colonization. The spots gradually coalesce and expand on the petioles and stems (Plate 22). The infected leaves become yellow, then necrotic and senescence is accelerated. Severe infection may lead to premature defoliation and death of the vines (Plate 23). Fruits are not infected usually but remain undersized, deformed, ripen prematurely and lack flavour. Yield reduction is proportionate to the time and severity of disease development.

Downy mildew

Causal organism: ***Pseudoperonospora cubensis*** **(Berk and Curt.) Rostow**

Symptoms

The disease appears initially as mosaic mottling with light and dark green areas on the leaf surface, which turn distinctly angular, bounded by veins, become yellow and then necrotic. Corresponding abaxial surface shows fungal growth in the early stages

under cloudy weather. Symptoms remain as numerous small necrotic spots if the weather becomes unfavourable for the disease or may enlarge to larger areas leading blight and the whole leaf dies under favourable environmental conditions. (Plate 24) Though the cotyledons may be invaded, five to fifteen days old leaves are more prone to infection. The whole vine weakens and wilts in severe infection Pathogen perpetuates in form of active mycelium on self sown or cultivated crop growing in sheltered places during severe winter. The disease in field through dispersal of sporangia. Young leaves are less susceptible than older leaves.

BACTERIAL

Bacterial wilt

Causal organism: ***Erwinia tracheiphila***

Symptoms

Drooping of one or more leaves of a vine followed by drooping and wilting of all leaves and collapses of vine of infected plant. Wilted leaves shrivel and dry up, affected stems first become soft and pale but later they too shrivel and become hard and dry up. The bacterium survives for only a week in the infected plant debris. It survives/ overwinter in the intestine of striped cucumber beetles and spotted cucumber beetles in which it hibernates. The pathogen is spread by contaminated mouthparts of beetles. The presence of the bacteria in a wilted stem often can be detected by simply cutting the stem and observing the bacterial ooze exuding out of the cut stem.

Angular leaf spot

Causal organism: ***Pseudomonas lachrymans*** **(E.F.Sm & Bryan) Carsner**

Symptoms

The infected foliage appears as water-soaked, irregularly shaped and angular spot. It then turns a tan color and dies. Dead tissue may tear away from the healthy tissue leaving holes in infected leaves. Fruit infected with the bacteria become water-soaked, develop circular spots and exude a white crusty bacterial substance. Bacterial soft rot usually follows which can cause decay of the entire fruit. The pathogen is carried on and in diseased plant refuge and on the seed. The pathogen is disseminated by splashing rains which carry the bacterium to new plants and to other parts of infected plants. The bacteria enter through the stomata (natural openings on surface of leaves or stems) or through wounds. It does not enter the vascular tissue as in wilt but rather remains in the foliage causing a leaf spot. Warm, moist weather conditions favor disease development.

Bacterial leaf spot

Causal organism: ***Xanthomonas cucurbitae*** **fsp** ***cucurbitae*** **(Bryan) Dowson**

Symptoms

Spots appear mainly on the leaves some times young stem and petiole may be attack. Water soaked area enlarge and turn brown with age surrounded by a yellow halo. Linear lesions are formed on stem and petioles. Spot may coalesce and form larger spot. The pathogen survives in soil in plant debris and in the seed.

VIRAL

Mosaic virus

Causal organism: Cucumber mosaic virus

Symptoms

Infected seedlings become small, turn yellow and finally die. Symptoms on older plants include dwarfing of plants, mottling, distortion and downward curling leaves. Infected fruit reveals patterns of white blotches interspersed with dark green spots that are raised into conspicuous blisters (Plate 25). Infected fruit has a bitter taste when eaten or becomes soggy when pickled. The virus survives the winter in roots of susceptible plants, in greenhouses, and possibly in seeds of wild cucumbers. Mode of transmission are aphids, cucumber beetle and by workers picking cucumbers.

Leguminous Crop

Pea (*Pisum sativum* L.)

FUNGAL

Pythium seed and root rot

Causal organism: *Pythium aphanidermatum* (Edson) Fitzp
Pythium debryanum

Symptoms

The disease can be identified by the poor stand of crop or scanty seed germination or seedling stand. Radicals or plumules may become soft, watery and translucent with or without rotting of the cotyledons. In seedling stage, stem and main taproot are the main sites of infection. Pathogen is common soil inhabitant that persists in crop debris as sporangia or oospore.

Fusarium wilt

Causal organism: *Fusarium oxysporum* schlechtend ex Fr. fsp *pisi* (J.C.Hall)

Symptoms

The initial symptoms are seen at or after blossoming time. Foliage becomes yellow with the leaflets and stipules curling downwards and inwards, a typical symptom of vascular disease. The foliage withers from the base of the plant upwards and death ensures before pod formation or before swelling. The root system visually appears normal but when sectioned longitudinally, vascular system looks yellow to orange colour. This vascular discolouration may extend upto basal stem of the infected plant. After death of the host, the pathogen grows out of the vessels and a white stromatic mycelium with heavy sporulation is found on the stem surface especially under conditions of high humidity. Near wilt symptoms are similar to those of wilt but develop more slowly. The pathogen is seed borne as well as soil borne.

Fusarium root rot

Causal organism: *Fusarium solani* (Mart.) Sacc. f.sp *pisi* (F.R. Jones) Snyder & Hansen

Symptoms

Yellowing and wilting of the leaves is main characteristic of this disease. The cortex

of the host root and hypocotyl become blackened and rotted, resulting in chlorosis and stunting of the plant. Often there is a red discoluration of the root vascular system but it does not progress above the soil line. The external root colour becomes dark reddish brown, especially at the ground line and in the seed zone. The lower root system may be completely decayed. Fungus survives through the chlamydospores which persist in soil and crop debris.

Anthracnose

Causal organism: *Colletotrichum gleosporioides* (Penz.) Penz. And Sacc

Symptoms

Spots on pods, stems and leaves are sunken, grey and circular with dark borders. When fruit bodies are formed in these spots, the setae of the acervuli can be seen with hand lens. Clusters of orange pink spores are borne in acervuli that are formed especially in pod lesions. Abundant spore production causes the stem to appear copper coloured when moist and ashy grey when dry. The pathogen persists as crop debris and on seed.

Powdery mildew

Causal organism: E*rysiphe pisi* DC. (Syn: *E. polygoni* DC)

Symptoms

The initial symptoms are small, diffuse, off-coloured spots on the upper surface of the lowest and oldest leaves. These lesions appear later as white, powdery areas. Tissue beneath these infected areas may turn purplish, after which small, black clestothecia are formed in the mature lesions. Leaves stems and pods may become infected resulting in withering of foliage and occasionally plant death (Plate 26). Severe pod infection may result in hollow peas.

Downy mildew

Causal organism: *Pernospora parasitica* (Pers. ex Fr.) Fr.

Symptoms

The disease first starts on the lowest leaves and then progress upward. Fluffy white cottny patches appear on the lower surface of the leaflets and upper surface turns yellow, brown and dries up. If the weather remains favourable, these lesions become large and cover the major portion of lamina. The disease can also appear on pods when they are young, green and flat. Infected pods are deformed and are covered with yellow to brownish areas and superficial blistering (Plate 27). The pathogen is primarly seed borne through oospores lying in diseased plant debris.

Ascochyta foot rot and blight

Causal organism: *Ascochyta pinodes* Jones

Tel: *Mycosphaerella pinodes* (Berk and Blox.) Vestergr.)

***Ascochyta pisi* Lib.**

Symptoms

Mycosphaerella pinodes produced lesions on leaves appearing as small purplish

areas which can remain restricted and lack a distinct margin becoming black to brown with a definite outer ring. Infection usually spreads from the leaves to the petioles and then to the stem, causing girdling lesions, which may coalesce and thus give the entire stem a blue-black colour. On the flowers, infections start as pinpoint lesions on the petals. *Ascochyta pisi* causes light brown lesions that have a prominent dark margin and pale centre. When infected seed germinates primary lesions develop on the first leaves. The pathogen can cause pre and post emergence damping-off and dwarfing but essentially attacks on the aerial plant parts. Pathogen can survive in infected plant debris. They are also seed borne.

Rust

Causal organism: *Uromyces fabae* (grev.) Fuckel.

Symptoms

The initial symptoms of the fungus are characterized by yellow spots having aecia in round or elongated clusters. The symptoms on leaf appear as elliptical blisters or pustules on both surface of leaves. The epidermis covering the pustules is later ruptured and pushes back, revealing a powdery mass of yellow coloured urediospores. Teliospores develop from same mycelium or uredinia on leaves, stem and petiole which are dark brown or almost black in colour. Fungus is mainly soilborne as teliospores in crop debris. It also survives on weed host.

Septoria blotch or leaf spot of pea

Causal organism: *Septoria pisi* Westend.

Symptoms

This is a common disease of pea throughout the world but confined to old and senescing foliage, stems and pods. Hence, it is not considered a major disease of this crop. Diseased areas on pea foliage are of indefinite size, shape and are yellow which turn later into straw colour. Several such blotches may coalesce to cover the entire leaflet or stipule. Numerous pinpoint sized black fruiting bodies called pycnidia develop in a scattered manner over the blotched areas on the foliage. Usually the disease is found on the lower, senescing portions of the plant and pods. In severe infection, diseased plant parts dry out prematurely. The pathogen overwinters in infected plant debris and is the main source of primary inoculum.

Cercospora leaf spot

Causal organism: *Cercospora pisi* Sativai Stevenson
C. *lachyrina* Ellis and Everch.

Symptoms

The symptoms of appear as numerous small, circular to angular lesions, scattered over the leaves. Lesions are brown, fading to grey or white at the centre with a slightly raised dark border. Fructification of the fungus is seen more often in the lower surfaces of the leaf. These appear as very minute black dots. The fungus survives on crop debris in form of stromatic masses.

Aphanomyces root rot

Causal organism: *Aphanomyces euteiches* Drechs f.sp *pisi* Pflender & Hagedorn

Symptoms

The first symptom of disease appears on the roots, straw-coloured lesions which spread through the cortex, resulting in the discoloured root system. Colonization of the epicotyl generally occurs soon after root system develops. The cortical tissue becomes watersoaked and straw coloured then softens and begins to slough off. The inability of the damaged root and epicotyl to provide the shoot with adequate moisture and nutrients results in the typical shoot symptoms. Plants may be severely stunted if infection occurs early. Leaves start yellowing progressively from the bottom of the shoot upward. Primary inoculum of pathogen generally persists as oospores on plant debris in the ploughed layer of soil. Another source of primary inoculum is maintenance of alternate host.

BACTERIAL

Bacterial blight

Causal organism: *Pseudomonas syringae* f.sp *pisi* (Sackett) Young, Dye & Wilkie

Symptoms

The disease is distinguished by the formation of shiny and watersoaked spot on leaves which later become dark, necrotic, papery and lighter in center. At flowering stage, sepals are readily infected and cause dropping of blossom and small pod. This is disease transmitted by seed.

BEANS

French bean (*Phaseolus vulgaris* L.)

Cowpea (*Vigna sinessis* Savi)

Dolichos bean or lablab bean (*Dolichos lablab* L.)

Lima bean (*Phaseolus lunatus* L.)

Cluster bean (*Cyamopsis tetragonolobus* L. Taub.)

Winged bean (*Psophocarpus tetragonolobus* (L.) D.C.

Broad bean (*Vicia faba* L.)

Soybean (*Glycine max* L.)

FUNGAL

Damping off

Causal organism: *Pythium aphanedermatum* (Eds.) Fitz

Symptoms

The disease is characterized by toppling over of infected seedlings after they emerge from the soil. Infection usually occurs at the ground level or through roots. Severely infected plants may die shortly after germination or emergence. These wilting plants soon die, leaving additional spaces within the rows. The infected tissues appear as soft and water soaked lesion. As the disease advances, the stem becomes constricted at the base and plant

collapse. The fungi are more active in cool, wet, rich soils. The pathogen is either seed or soilborne or both.

Root rot and web blight

Causal organism: ***Rhizoctonia solani*** **Kuhn, Tel:** ***Thanatephorous cucumeris*** **(Frank) Donk**
Fusarium solani **f. sp.** ***phaseoli*** **(Burk) Snyder and Hensen**
Pythium spp

Symptoms

Rhizoctonia can cause seedling blight, root as well as hypocotyl rot, and stem cankers. Symptoms are characterized as reddish brown sunken lesions surrounded by a reddish brown margin. The lesions enlarge with age, become darker and rough-textured. The fungus can cause a brick red discoloration of the central part of the lower stem.

Fusarium root rot is initially identified at seedling stage of plant by reddish coloured lesions on the taproot and hypocotyl which later turn brown in colour. This discolouration can extend up to the soil line. Seriously infected plants are stunted and with yellow leaves. Branch roots are killed. Longitudinal cracks may develop in older hypocotyl lesions.

Pythium may affect seeds, seedlings and young or old plants. Symptoms are elongated water-soaked areas on the hypocotyls and roots 1-3 weeks after planting. This water soaked region may be present several inches above the soil line. Early in the infection process, the outer tissue of the stem splits easily from the central core. It eventually dries out, becomes thin and sunken and turns brown.

The pathogen perennates in the soil on disease plant debris as mycelium or sclerotia.

Anthracnose

Causal organism: ***Colletotrichum lindemuthianum*** **(Sacc. & Magn.) Scribner**
Tel: ***Glomerella lindemuthianum*** **(Sacc. & Magn.) Shear**

Symptoms

Pathogen attacks on the under surface as blackened dead portions of the leaf veins. Later, such spots appear on the upper leaf surface. Lesions are also formed on petioles and stems as well as on immature pods. On pods black sunken cankers, with lighter coloured or grey central area are seen. The central portion of the spot shows pinkish masses of spores of the fungus especially in wet weather. The seeds obtained from heavily infected pods show brown to light chocolate coloured sunken cankers on the seed coats. Seeds with less severe infection show yellowish to brown sunken lesions but are not always easy to distinguish from those causes by certain other organisms. The fungus is soil and seed borne. In soil it survives on diseased plant debris but cannot live long when separate from the debris. Infected seed also develop first lesion and initiate the disease in crop.

Fusarium root rot

Causal organism: ***Fusarium solani*** **(Mart.) Appel &Wollenw f. sp.** ***phaseoli*** **(burk.) Snyder &Henson**

Symptoms

The disease is characterized as reddish lesions or streaks on the hypocotyl and primary root. As infection progresses, the lesions coalesce and become brown, later may extend to the soil surface. The lesion increases longitudinally. The primary and lateral roots are frequently attacked by the fungus and killed. There are no pronounced wilt symptoms, though plant growth may be retarded and exhibit leaf yellowing and premature defoliation (Plate 28). Pathogen exist in naturally infested soil as chlamydospores associated with or embedded in tissue or humus particle.

White mold

Causal organism: *Sclerotinia sclerotiorum* (Lib.) de Bary

Symptoms

Disease is characterized as white cottony growth of fungus on the stem, stem branches and pods of bean. The fungus produces black, sclerotia near these cottony growths. Sclerotia allow the organism to survive in adverse (winter) conditions. The disease cycle starts when the leaf canopy covers the row spaces and when the soil surface is cool but moist enough for the sclerotia to germinate. Upon germination, small mushroom-like bodies called apothecia appear on the soil surface. Spores are produced by the apothecia and infect wilted flowers or other dead plant tissue, later spreading to living plant tissue (Plate 29-31).

Powdery mildew

Causal organism: *Erysiphe polygoni* DC

Symptoms

It is characterized by white powdery growth appear on the leaves which spread and cover the stem and other plant parts. The entire plant dries up in severe infection. The pathogen survives in form of conidia on the annual or perennial leguminous crop.

Cercospora leaf spot

Causal organism: *Cercospora cruenta* Sacc.

***C. canescens* Ellis & Martin**

Symptoms

Cercospora leaf spot disease is the most common disease of bean. Disease is identified as reddish brown or rust coloured spots appear on the leaves which may coalesce and vary in shape (circular to angular) and size (2-10 mm). *C. canescens* produces irregularly shaped light brown lesions with a grey centre in the leaves, pods, stems and branches. Later sporulation of the fungus can be noticed in the grey portion as dark growth. Lesions may dry and centre portion may fall out leaving a hole. *C.cruenta* may cause numerous lesions on primary leaves but seldom infect the trifoliate ones. Blemishes may occur on stems and pods. Both pathogens may become seed borne in nature. Pathogen survives in plant debris and carried long distances on or in the seed.

Alternaria leaf spot

Causal organism: *Alternaria* spp

Symptoms

Spots appear as irregular shaped lesions and are usually dark to grey brown. Under favourable conditions, lesions coalesce, forming large contiguous areas. *Alternaria* survives in infested crop and weed residue and may infect leaves through wounds. Disease is favored by wet and moist conditions and is found most prevalent on mature or senescent leaves.

Angular leaf spot

Causal organism: *Phaeoisoriopsis griseola* (Sacc.)

Symptoms

Symptoms are characterized by reddish to greyish spots without borders appear on upper surface and slightly lighter grey on the lower surface of the leaf which are consistently delimited by veins. Seed borne infection results in circular spots on primary leaves and angular spots on trifoliate leaves, stems and petioles. In severe infections, leaves show upward curling and defoliate prematuely. The fungus also attacks the pods causing superficial, smooth, usually circular spots with reddish brown centre and ashy black borders. Under severe conditions of infections, these spots coalesce causing complete defoliation. Yellowish brown discolouration is also observed on infected seeds located underneath the pod lesions (Plate 32-36). The pathogen perpetuates both on crop debris and in infected seed.

Rust

Causal organism: *Uromyces phaseoli typical* Arth
***Uromyces phaseoli* Fr.**

Symptoms

The disease is more common on the lower surface of the leave and it appears as small, slightly raised and white colour rust pustules. These pustules enlarge to form reddish brown, sori up to 2 mm in diameter, containing the rust spores. After coalescing, they may occupy larger areas. A ring of secondary sori may develop around the original infection. Telial stage is dark brown to black coloured and linear. Leaves may turn yellow and dry or they may fall off. It is not a seed borne fungus. In region with cooler climate it can survive through teliospore in crop debris.

Floury leaf spot

Causal organism: *Mycovellosiella phaseoli* (Drummond) Deighton

Symptoms

White growth of the fungal conidiophores on the lower surface of leaf appeared as sprinkled with coarse flour, hence the disease is named as floury leaf spot. The corresponding upper side of the leaf turns yellow, then brown and finally dried up. Young leaves are less susceptible. The pathogen perpetuates on the infected plant debris in the soil and serves as source of primary inoculum.

Aschochyta leaf spot

Causal organism: *Aschochyta phaseolorum* Sacc.

Symptoms

The leaf spots are circular, brown and crowded with minute black fruiting bodies of the fungus. Usually the spot are marked with concentric zones and dark black margins. The leaves may die in presence of too many spot. The fungus is soilborne in infected crop debris and also seed borne in nature.

Diaporthe pod blight of lima bean

Causal organism: *Diaporthe phaseolorum* (Cooke & Ellis)

Symptoms

Disease is appeared as irregularly shaped brown lesions surrounded by a distinct border on the leaf. As the tissue die, large dark pycnidia of the fungus are seen in concentric circles in the lesion. The dead portion ultimately falls out leaving holes in the leaf. If infection occurs before seed formation, they may be seedless. The fungus perennates in affected seed as well as in plant debris.

BACTERIAL

Bacterial blight

Common blight : ***Xanthomonas campestris* pv. *phaseoli* (Smith) Vauterin *et al***

Halo blight : ***Pseudomonas syringae* pv. *phaseolicola* (Burkholder)**

Brown spot : ***Pseudomonas syringae* pv. *syringae***

Symptoms

Common bacterial blight first appears as small translucent water-soaked spots on the leaf. These spots are not larger than one mm in diameter. As these spots enlarge, this tissue dies leaving brown spots with a narrow yellow margin. Lesions are often large and irregular in shape. In some cases, a yellowish discharge may be observed. Water-soaked sunken lesions can be present on pods. These pod lesions later turn brownish-red. Bacteria may infect the vascular system and kill the main stem and branches. The bacterium overwinters in infected seed, crop debris and weed host.

Halo blight infected plants exhibit symptoms like common blight but the waters soaked brown spots are one cm or more in breadth size and have a large pale yellow to halo around them. This halo may be 1/2 inch in diameter. The bacterial fluid found is cream or silver in colour. Systemic plant infection produces small chlorotic on the leaves. Red or brown water soaked lesions appear on the pod. The bacterium is mainly seed borne.

Brown spot lesions are similar to those of common blight with a narrow yellow border (not a halo) surrounding the lesions although water soaking of the leaf tissue is generally absent. When lesions mature, the dead tissue in the center falls out resulting in a shot hole. Infected pods may be twisted at the infection point (Plate 38).

Bean common mosaic

Causal organism: Bean common mosaic virus

Symptoms

Bean common mosaic virus (BCMV) causes mottling, leaf malformations and

stunting. Infected leaves are irregular in shape, light yellow and green patches and may also show puckering. Infected leaflets are narrower and longer than normal with a downward cupping. Bean plants infected early in the season are yellowish, dwarfed and spindly. Dark necrotic lesions are sometimes found on the roots, petioles, and leaf veins. Small dark necrotic spots may also develop on leaves and pods (Plate 39). The virus spreads by direct contact, by aphids and by seed. This virus is moreover transmitted through bean seeds.

Root knot nematodes

Causal organism: ***Meloidogyne incognita***
M. javanica
M. arenaria

Symptoms

It is characterized as formation of galls on the roots. Nematode damage plant by devitalizing root tip and causing formation of swelling of the root. The above ground symptoms are reduced growth and fewer small pale green or yellowish leaves that tend to wilt in warm weather. Blossoms and fruits are few and of poor quality. The pathogen is soilborne and its dispersal is also mainly through soil.

BULBOUS CROPS

The major crops in the group includes *Allium cepa* L. (onions) and *A. porrum* L. (leek) and *A. sativum* L. (garlic). There are a number of pathogens that attack *Allium* spp.

Onion (*Allium cepa* L.)

Garlic (*Allium sativum* L.)

FUNGAL

Purple blotch

Causal organism: ***Alternaria porri*** **(Ellis) Cif**

Symptoms

The disease is identified as small water-soaked lesions on leaves or seed stalks that rapidly develop white centers. As the lesions grow in size, they become zonate and brown to purple in colour. The margin of the lesion is often a shade of red or purple and is surrounded by a yellow zone (Plate 40). In moist weather, the surface of the lesions may be covered with brown to dark grey masses of spores. Seed stalks, flowers of seed onions and at harvest, bulbs may become infected. The main source of perennation of the pathogen is dormant mycelium which remains alive in diseased crop residue.

Stemphylium leaf blight and stalk rot

Causal organism: ***Stemphylium vesicarium*** **(Wallr) E. Simmons**
Tel: ***Pleospora allii*** **(Rabenh) Ces. & de Not**

Symptoms

Disease is distinguished as small, light yellow to brown and water-soaked lesions develop on leaves. These small lesions grow into elongated spots that frequently coalesce

resulting in blighted leaves. Lesions usually turn light brown to tan at the center and later give dark olive brown to black color on the leaf. The fungus overwinters in the plant debris. In growing season, it infects plants after long warm periods when leaves remain wet.

Onion blast

Causal organism: ***Botrytis allii*** **Munn.**
Botrytis byssoidea **Walker,**
Botrytis squamosa **walker**
Botrytis cepa **Hanzawa**

Symptoms

Symptoms appear as a large number white speck with necrotic centres (2 mm in diameter) surrounded by a light green halo (1-1.5mm in width) which take an elliptical shape. Under prolonged moist conditions, the fungus develops rapidly and causes blighting of leaves. The pathogen overwinters as sclerotia or mycelium on the crop debris. Sclerotia upon germination produce conidia and serve as source of primary inoculum.

Botrytis leaf spot

Causal organism: ***Botrytis cinerea*** **Pers**

Symptoms

Botrytis leaf spot occurs mainly on onion. The disease is diagnosed as a small white lesion with necrotic centers which are surrounded by a light halo on the leaf surface. The fungus survives on old bulbs or onion leaf debris as sclerotia or mycelia and in soil as sclerotia (Plate 41). Spores produced from infested soil or plant debris are carried to onion leaves by wind or splashing water.

White rot

Causal organism: ***Sclerotium cepivorum*** **Berk**

Symptoms

Foliage symptoms are not apparent until the fungus grows into the root and basal part of the bulb. Disease symptoms include yellowing, leaf dieback and wilting. Older leaves are affected at first, followed by stunting of plants and death of all foliage. Root rot also occurs. Plants may suddenly die in large areas of the field if the soil is heavily infeeted. The pathogen is soil inhabitant and survives for several years as sclerotia in absence of host plant.

Fusarium basal rot

Causal organism: ***Fusarium oxysporum*** **Schlechtend ex Fr fsp** ***cepae*** **(Hans) snyd. & Hans**

Symptoms

Garlic and onion bulbs may become infected at any time in the field. The pathogen attack bulbs which later covered with a whitish mycelium (Plate 42). The primary symptoms of the disease are curling, yellowing, necrosis and withering of the leaves. Infected plant shows reddish or reddish purple discolouration on stems and bulbs early

in the season with some discolouration on bulb sheaths at harvest. Affected plants also show wilting symptoms. Infected stem show a brown discolouration. The planto can be easily pulled out showing decay of almost all the roots. Infected plants may display no decay at harvest but subsequently rot in storage. Pathogen is soil inhabitant and long term survival is by means of chlamydospore.

Management

Soft rot or Southern blight

Causal organism: ***Sclerotium rolfsii*** **Sacc**

Tel: ***Athelia rolfsii*** **(Curzi) Tu & kimbrough**

Symptoms

Disease symptoms include dirty white spots on the outer scales and lesions on the neck area giving water soaked appearance to the affected area. Under favourable condition, the spots increase in size and the whole bulb becomes pulpy. A mycelium may form on the bulb which spread to the surrounding soil and organic matter. Brown colour sclerotia also form on the bulb and debris. Infected bulbs easily disintegrates into a watery mass. The fungus survives as mycelium, rhizomorphs and sclerotia in soil. It may spread through the soil and form plant to plant contact. Sclerotia produced on plant debris surives as inoculum for the next crop (Plate 43).

Onion smut

Causal organism: ***Urocystis cepule*** **Frost**

Symptoms

Typical elongated dark, slightly thickened areas on the cotyledon that cover one to several milimeter of the surface. Mature lesions contain exposed, black, powdery spore masses on the leaf. Infection progresses inward from leaf to leaf and infected plants become stunted and may die within 3 to 4 weeks after emergence (Plate 44). If the plants survives, the disease becomes systemic and they remain till vegetative stage for the entire growing season. The bulbs also become covered with blackish lesion which are liable to infection by other pathogens. The fungus overwinters in soil and persists for many years.

Onion smudge

Causal organism: ***Colletotrichum circinans*** **(Berk) Volino**

Symptoms

The disease affects the scales of the onion and it is characterized as appearance of subcuticular dark green to almost black, minute stromata just beneath the cuticle on the bulb. Stromata may be scattered over the surface of the lesions, but they frequently form in circular, concentric rings approximately 1 cm in diameter. Inner scales are also attacked if the outer scales have been peeled off. On these inner scales the l esions are small, sunken and yellow (Plate 45). In humid weather, pinkish masses of spores develop on the black stomata. The pathogen is soilborne and persists as stromata in colonized onion scales and plant debris or as a sporophyte for several years as mycelium.

Pink rot

Causal organism: *Phoma terrestris* Hansen

Symptoms

Infected onion roots are initially light pink in colour, gradually turning deeper pink and finally dark purple as the disease progresses. As new roots are produced, they are infected, turn pink and eventually die. Plants become stunted in severe infection and may appear to be suffering from drought or a nutrient deficiency but usually do not die. The fungus perennates in the soil on the crop debris and spreads by mean of bulb and seedling.

Downy mildew

Causal organism: *Peronospora destructor* (Berk.) Casp

Symptoms

Disease symptoms are recognized as elongated patches upto 1.25 inch long and pale in colour which turns a light tan to brown in colour. Greyish violet growth of fungus visible on the surface of infected leaves or seed stems during moist periods especially early morning. Downy mildew lesions may be violet to purple. Infected leaves gradually turn pale green to yellow and diseased parts such as leaf tips fold over and collapse. The fungus overwinters in volunteer plants as oospore and also persists as mycelium in infected bulb in storage.

Powdery mildew of garlic

Causal organism: *Oidiopsis* spp

Symptoms

Symptoms of powdery mildew on garlic causes light yellow to silvery white patches on leaves within which single spores (conidia) on clusters of stalks (conidiophores) emerge from stomatal openings. If disease appears on younger plants, applications of sulphur may be warranted. Sulphur should be applied as soon as disease is observed.

Bacterial soft rot of onion

Causal organism: *Erwinia caratovora* (Jones) Hollond

Symptoms

Symptoms begin at the neck of the bulb and later on it gives foul sulphurous smell through the neck when squeezed. Sour skin rot affects only some of the outer scales and is characterized by slimy and yellow appearance of affected scales which give off a vinegar like odour. The outside scale slipes of readily during handling.

Leak (*Allium porrum* L.)

White tip of leek

Causal organism: *Phytophthora porri* Foister

Symptoms

The tip of leaves become yellow and turns white. In severe attack, leaves turn backward. Water soaked area in the vicinity of the midrib may appear half way on the leaf or near the base.

CRUCIFEROUS CROP

Cauliflower (*Brassica oleracea* L. var *botrytis*)

Cabbage (*B. oleracea* L. var *capitata*)

Knolkhol (*B. caulorappa* L.)

Broccoli (*B. oleracea L.* var *italica*)

Brussels sprouts (*B. oleracea L. gemmifera Zenk.*)

FUNGAL

Damping off

Causal organism: *Pythium debaryanum* Hesse.

Symptoms

Damping off occurs in two stages: (1) pre emergence phase and (ii) post-emergence phase. In pre-emergence phase, the young seedlings are killed before they reach the soil surface. Post-emergence phase is characterised by toppling over of the infected seedlings. Stem base gets constricted at the point of infection and becomes discoloured. In full-grown cabbage plants, the pith of the head shows a soft and watery rot (Plate 46). Pathogen colonizes on the death plant organ in soil and quickly form oospore. Pathogen enters in the soil through precolonized host residue carrying oospore and sporangia which are survival structure. The pathogen is soil borne in nature.

Wire stem

Causal organism: *Rhizoctonia solani* Kuhn (Tel: *Thanatephorus cucumeris* (Frank) Donk.)

Symptoms

The pathogen mainly kills the seedlings prior to their emergence. It is characterized as soft, watersoaked spots on the stem near collar region and the plants eventually topple down. The lower part of the stem that often shows dark discolouration and become hard and thinner. This phenomenon is known as wire stem. In plants, it causes bottom rot in which lower leaves droop and dry out turn dark. The infection may extend to the upper leaves and eventually reaches the head causing head rot. The first infection is brought about by the sclerotia that is survival structure of pathogen.

Sclerotinia rot

Causal Organism: *Sclerotinia sclerotiorum* (Lib.) de Bary

Symptoms

The disease first appears as wet soft lesions on cauliflower curd and leaf scar on the stump region of cabbage head. These lesions enlarge into a watery rotten mass of tissues that is covered by white silvery appearance. Infection of stems, curds, heads, branches and inflorescence causes affected plant parts to wilt and later die. Affected crop lose their turgidity and fail to grow flowering shoots. There is development of variable size sclerotia (resembles the size and weight of radish or bean seeds) in and on affected parts are characteristic of Sclerotinia rot in cool and humid weather. The below ground parts show watery soft rot and excessive shredding of tissues containing black and

irregularly shaped sclerotia. S. *sclerotiorum* never produces an odorous rot on any of the crops unless other organisms follow and further decompose the tissue (Plate 47). The pathogen survives from year to year as sclerotia in soil or plant debris.

Yellows

Causal Organism: *Fusarium oxysporum* Schlechtend ex. Fr. f.sp. *conglutinans* (Wr.) Snyder and Hansen

Symptoms

The disease is distinguished in the plants at any stage from seedling to maturity. The foliage turns yellow, dies and eventually drops off, lower leaves being the first to show these symptoms. Young seedlings occasionally affected plant remains stunted and pale inspite of sufficient fertilization. The fleshy fibrous roots gradually become watersoaked with extensive vascular discolouration. Heavy infection causes death of plants, but sudden withering does not usually occur. The pathogen is soil borne and survive as saprophyte on diseased plant debris as well as resting chlamydospores in absence of cruciferous crop.

White rust

Causal Organism: *Albugo candida* S.F. Gray (Syn: *Cystopus candida* (Pers. Ex Chev.) Kuntze)

Symptoms

Local infection appears as results in isolated pustules in stem and leaves which shows characteristic raised glossy white blisters 1 to 2 mm in diameter. Systemic infection stimulates hypertrophy and hyperplasia resulting in enlarged and variously distorted organs. The inflorescence may become enormously thickened (12-15 times the normal thickness), fleshy and greenish leading to sterility. The thickened inflorescence is generally known as stag head. Blisters after rupturing the host epidermis release white powdery mass comprising of asexual sporangia. The fungus perpetuates through oospores lying in the soil in diseased plant debries or moving with diseased pieces along with seed. Perenial weed may also serve as source of primary inoculum.

Alternaria leaf spot

Causal organism: *Alternaria brassicae* (Berk.) Sacc.
***A. brassicicola* (Schw.)**

Symptoms

Symptoms on young plants show black spots upto 2mm in diameter on the cotyledons and on the hypocotyls and the plant eventually die. In older plants, the leaves, spots upto 1 cm in diameter, surrounded by dark brown to black concentric rings. The spots caused by *A.brassicae* are smaller and lighter in colour than those of *A.brassicicola.* The outer leaves in cabbage may rot and infection may extend to the inner leaves rendering the product unmarketable (Plate 48). Slightly depressed lesions appear in root crops. Seed crop plants exhibit black to brown spots on flower stalks and siliques. Early stage of infection of siliques ultimately results in curling. Seeds harvested from such siliques are

frequently contaminated and possess reduced vigour. Pathogen is seed borne. Spore and mycelium in diseased plant debris also serve as mean of perenation.

Black leg

Causal organism: ***Phoma lingam*** **(Tode ex Fr.) Desm**

Tel: ***Leptosphaeria maculans***

Symptoms

Disease is distinguished as reddish brown to black pycnidia present as small dots on the hypocotyls and on the cotyledons of young plants resulting into their death. In the advance stage, the base of stem shows sunken greyish-brown oval spots, sometime with a purple or black margin which may extend over the entire stem surface and may also damage the cortex of root. In the favourable condition, proportion of black legs increases and badly affected plants topple over due to increasing top weight. On the leaf, the fungus produce sunken, irregular greyish spots with a purplish to black margin on the leaf, while sometime elongated spots occur on the petioles. The vascular bundles of the head core may show black discolouration. The lower stalks and siliques also infected and develop typical Phoma spots. Eventually the seed is also infected and give final stage of the infection cycle. The black leg epidemic starts from the infected seed. The fungus persists as dormant mycelium in seed or on infected residues.

Club root

Causal organism: ***Plasmodiophora brassicae*** **Wor**

Symptoms

The most characteristic symptoms of the disease consist of small or large, spindle like or spherical, club shaped swellings on the roots and rootlets. The hypertrophy causes malfunctioning of the vascular tissue and the water supply to the plant is disturbed which results in pale green to yellowish foliage, flagging and wilting of plants. Affected plants show decline in vigour first and can partly recover by forming adventitious roots. The infected roots may rot and perish as a result of secondary infection. The pathogen survives through its resting spores lying free or in the crop debris.

Grey mold

Causal organism: ***Botrytis cinerea*** **Fr.**

Symptoms

The disease is characterized as large watersoaked grey or brownish patches appear which soon become covered with greyish powdery fungus growth consisting chiefly of the conidiophores and conidia of the pathogen and eventually black small sclerotia form on the rotting tissue plant. The attack on the sprout often originates in injured leaves or on foliage damaged by other fungi, where *Botrytis* becomes established for initiating further infection. The grey mold fungus often follows *Phoma lingam* and the development of dry rot may be more or less masked, as *P. lingam* may be suppressed to a large degree by *Botrytis* which causes large soft water soaked areas to develop. Pathogen survives as living saprophytically on all kind of plant debris but capable of attacking plants in a damaged state.

Downy mildew

Causal organism: *Peronospora parasitica* (Pers. Ex Fr.) Fr.

Symptoms

The first attack of the pathogen on hypocotyl and cotyledons of invaded young seedlings which become discoloured and drop early. Symptoms as small, chlorotic, irregular, translucent, light green lesions on the leaf usually delimited by the veins appear under cool and moist conditions. Downy growth of sporangiophores on mature lesions is more pronounced on lower leaf surface. As the lesion dry out, they become necrotic. Black colour spots also develop on edible part of the plant. Black depressed lesions also occur on the flower stalks, buds, and siliques resulting in their distortion. The lesions develop downy growth of the fungus and fructifications during cool and humid conditions. The fungus perennates in soil through oospores. Seeds also carry oospores in contaminating trash which goes to soil with seed at time of sowing.

Ring spot

Causal organism: *Mycospharella brassicicola* (Fr.ex Duby) Lindau

Symptoms

On leaves, circular, brownish grey spots upto 2 cm in diameter appear, often with a number of clearly delimited, black specked concentric zones on which fructifications appear. Badly affected leaves often drop prematurely. The spots are more oblong or irregular in shape and they may occur over the entire surface of the stem or siliques. The young seedlings may also become infected, show discolouration and wither. Infected plant debris is the main source of primary inoculum. The fungus also perennates in seed.

BACTERIAL

Black rot of crucifers

Causal organism: *Xanthomonas campestris* pv *campestris* (Pammel)

Symptoms

Disease symptoms appear initially as large watersoaked often V-shaped chlorotic blotches at the margin of leaves. The chlorosis progresses towards the midrib of leaf while some of vein and veinlet within the chlorotic area turn black. The affected area later turns brown, dry and blackening of veins takes place. The stem and the stalks of infected leaves in cross section show blackening of vascular tissue, yellow slime droplets of bacteria and sometimes cavities full of bacteria in the pith and cortex. The bacteria overwinter in infected plant debris and on or in seed.

NON PARASITIC

Browning or brown rot or red rot

Boron deficiency

Boron deficient plant shows small, concentric water soaked area develops in the stem and also on the branches of the plant. The curds appear brown in colour and the small leaves on the curd become deformed. The stems may become hollow with water

soaked tissue. In more advanced stage, pinkish or rusty brown areas develop on the surface of curd. The affected curds give a bitter taste.

Whiptail

Molybdenum deficiency

The leaf blades of cauliflowers do not develop properly and may be straplike. In severe cases only midrib develops. The young cauliflower plant become chlorotic and may turn white, particularly along the leaf margin and they also become cupped and wither.

Buttoning

Physiological disorder

When cauliflower plants are young, they sometime develop very small heads. This may be due to overaged seedling, poor nitrogen supply and wrong cultivar crowding of plant or late planting

ROOT CROPS

Carrot (*Daucus carota* L.)

FUNGAL

Sclerotinia rot Causal organism: *Sclerotinia sclerotiorum* (Lib) de Bary

Symptoms

The disease first appears as wet soft lesions which enlarge into a watery rotten mass of tissues that is covered by white silvery appearance. Affected crop lose their turgidity and fail to throw flowering shoots. There is development of variable size sclerotia (resembles the size and weight of bean seeds) in and on affected parts are characteristic of *Sclerotinia* rot in cool and humid weather. The pathogen survives from year to year as sclerotia in soil or plant deleris.

Alternaria blight

Causal organism: *Alternaria radicina* Meier, Drechsler & Eddy

Symptoms

Disease is noticed as small dark brown to black spots develop along the leaf margin. The number of spots gradually increases and the interveinal tissue die. In the favourable condition, the whole leaflet die and shrivels. The blackening and shriveling progress so rapidly that the entire field exhibits frost injury in moist weather. In spite of the above foliage destruction the carrot roots are not affected in the field and in storage. The disease is seed borne in nature and pathogen also survives on the infected crop debris.

Leaf blight

Causal organism: *Alternaria dauci* (Kuhn) Groves & Skolko

Symptoms

The fungus causes black sunken, irregular to circular lesions on the leaf. The decayed tissue is greenish black to jet black due to presence of masses of black spores. The disease affects roots in the field as well as in storage. This fungus is seed and residue-

borne. Complete loss of foliage can take place during periods of prolonged wet, humid weather.

Cercospora leaf spot

Causal organism: *Cercospora carotae* (Pass.) Solheim.

Symptoms

The chief symptoms develop in the form of elongated lesions along the edges of the leaf margin. The infected leaflet shows lateral curling. Small pin pointed chlorotic spots develop in the middle of the leaf which soon turns into necrotic center surrounded by a diffuse chlorotic border. The spots may coalesce to form bigger spots.

Powdery mildew

Causal organism: *Erysiphe polygoni* DC

Symptoms

The disease is characterized as white powdery mass of ectophytic mycelium on the leaves, flowers, stems and fruits. The underneath or lower surface of the leaf gives brown or purplish coloured growth of fungus.

BACTERIAL

Bacterial soft rot

Causal organism: *Erwinia carotovora* subsp.*carotovora* (Jones) Bergey *et.al*

Symptoms

This is a disease of storage and transit. The infected tissue softens and become watery or slimy and water extrusion become more evident as rot progresses. Disease can easily distinguishes by foul odour from it. The bacteria live in the soil and in the decaying refuse.

MYCOPLASMAL

Carrot yellows

Causal organism: Mycoplasma (Phytoplasma-like organism PPLO)

Symptoms

The disease symptoms on the leaves become yellow accompanied by vein clearing. Witch broom appearance is noticed from the dormant buds in the crown. Older leaves are reddish, twisted and may eventually break off. The internal texture, colour and flavour show marked damage causing reduction in the value of carrots for fresh market as well as for processing. Roots of infected plants have bitter and astringent flavour (Plate 49). The virus is mainly transmitted by leafhopper, *Macrosteles divisus*.

NEMATODES

Causal organism: *Pratylenchus* spp, *Meloidogyne* spp, *Longidorous* spp, *Trichodorous* spp

Symptoms

Several species of the migratory nematodes feed on carrots and cause stunting. The infected roots become unfit for market.

Radish (*Raphanus sativus* Linn.)

FUNGAL

Alternaria leaf blight

Causal organism: *Alternaria raphani* Grover and Skolko

Symptoms

The disease symptoms include small, yellowish, slightly raised lesions on the leaves. They enlarge in size as they become older. The pathogen also attacks the stems and pods. The entire pods may be infected during rainy weather which becomes black and shrivelled.

White rust

Causal organism: *Albugo candida* (Pers ex. Chev) Kunze

Symptoms

The symptoms appears on the leaves as white raised powdery substance which produce on the under surface of the leaves and flowering become deformed and bear only malformed flowers. The infected leaves get devitalized (Plate 50).

VIRAL

Radish mosaic

Causal organism: Radish mosaic virus

Symptoms

The typical symptoms develop on the leaves in the form of small, circular to irregular, chlorotic lesions in between and adjacent to the veins. The virus is transmitted by aphids.

MYCPLASMAL

Raddish phyllody

Causal organism: Mycoplasma

The pathogen attacks the plant during flowering. The sepal, petals and carpels of affected flowers show phyllody and the stamens become sapaloid.

Beet (*Beta vulgaris* L.)

FUNGAL

Cercospora leaf spot

Causal organism: *Cercospora beticola* Sacc

Symptoms

Disease symptoms appear as brown to grey with distinct reddish-purple borders on the leaf. Leaves become senescent and die prematurely. The fungus over winters in residue from diseased plants or on seed and is spread by splashing water, wind, insects, tools and implements used for cultivation, workers. High humidity and moderate temperatures promote disease development.

Downy mildew

Causal organism: *Pernospora schachtii* Fekl

Symptoms

Disease initially appears in the form of various sizes spots which develop on the leaves. The affected portion becomes lighter in colour on the upper surface. Downy fungal growth is seen on the under surface of the leaf. In dry weather margins of the leaves may have a pale red pigmentation. The infected leaves may become thicker and smaller than the healthy ones and are often curled downwards at the edges. Inflorescences may become smaller and distorted. Sepals and petals become swollen and mildew appears on all the affected parts in moist weather. The excessive leaf development may give witches broom appearance. The fungus survives on the plant debris in the soil.

Black leg

Causal organism: *Pleospora betae*

Symptoms

The symptoms of disease are characterized by withering and drying of leaves. The stems of young seedlings become blackened and shriveled. The pathogen is seed borne in nature.

Phoma heart-rot

Causal organism: *Phoma betae*

Symptoms

Disease symptoms include seedling damping-off, leaf spots and root rots. Leaf spots are characterized as light brown, have poorly defined margins which may enlarge upto 1 inch in diameter. Root rots begin as watersoaked areas that turn brown and finally black. Rots are dry and firm unless invaded by soft-rot bacteria. The causal fungus over winters on seed and in residue from diseased plants and is spread by splashing or running water.

VIRAL

Beet mosaic

Causal organism: Beet mosaic virus

Symptoms

The typical symptoms include the mottling of the leaves with chlorotic, zonatic ring spots. They become necrotic with age. Virus infected plants remain stunted and may lose some leaves. The virus is transmitted by aphids.

Heart and internal black spot

NON PARASITIC

Boron Deficiency

It causes black spots inside beet roots and large black dry rots on the root surface. Dead areas may appear on the inner surface of leaf stalks. These young unfolding leaves

may turn brown or black and die. A heart-rot may develop in the root where leaves were killed. Dead areas may develop at cambial rings within fleshy tap roots.

Turnip (*Brassica campestris* var. *rapa* L.)

FUNGAL

Alternaria leaf spot

Causal organism: *Alternaria* spp.

Symptoms

The pathogen attacks on the leaves, stem, pods and seeds. Disease symptoms are characterized in the form of small, yellowish, slightly raised lesions which appear on the leaves of seed stem. Lesions appear later on the stems and seed pods. Infection spreads rapidly during rainy weather, and the entire pod may be so infected that the stylar end becomes black and shrivelled. The fungus penetrates in pod tissues, ultimately infecting the seeds. The pathogen is seed borne and pathogen also survives on the infected crop debris.

Turnip phyllody

Symptoms

The symptoms of the disease appear at the time of flowering when all the floral parts become green violet and leafy. The diseased plant assumes a dull grey to light violet colouration. The sepals and petals become green thick knob headed leaves. Generally, the whole plants show symptoms of the disease. If the infection occurs at an early stage of growth in the nursery then the whole plant is affected. The disease is transmitted by jassid *Orosius albicinctus.*

Turnip crinkle

Causal organism: Turnip crinkle virus

Symptoms

The disease is characterized by crinkling of leaves. The infected leaves show yellow patches and are brittle in appearance. The yellow patches coalesce and become necrotic with age of the plants. Later on, the affected leaves begin to die and wither away. Severely affected plants show a stunted growth with a rosette appearance.

OTHER ROOT CROPS

Ginger (*Zingiber officinale*)

FUNGAL

Rhizome rot

Causal organism: ***Pythium aphanidermatum*** **(Edson.) Fitep.**
Pythium butleri **Subram**

Symptoms

Initially, the disease becomes apparent by slight fading of green colour of leaves. The tip of the leaves turns yellow and this cholorsis procedes downward ultimately

resulting in withering and death of the leaves. During progress of chlorosis, central portion of the leaf usually remain green. The base of the stem shows translucent brown discolouration and the portion just above the ground level become watery and soft. From the collar region, the pathogen gradually spreads to the rhizomes which decompose and turn into a decaying mass of tissue enclosed by comparatively trough rind. Infected rhizome used for seed are the main agents of introducing the fungus in field.

Colocasia (*Colocasia esculenta* L.)

FUNGAL

Pythium rot

Causal organism: ***Pythium*** **spp**

Symptoms

The primary symptoms appear as chlorosis of leaves and the affected plants gradually wilt. The corm become soft and rots with foul odour. The fungus is soil borne in nature.

Phytopthora blight of colocasia

Causal organism: ***Phytophthora colocasie*** **Racib**

Symptoms

The disease symptoms appear in form of small dark, concentric roundish spot on the leaf. These spots rapidly enlarge, coalesce and become circular and the entire leaf dies. Often, drops of yellow liquid ooze out from the affected areas. Later on the spots dry and the affected portions drop out giving a shot hole appearance. The spots are surrounded by brown, green and yellow shades. The fungus perennates through oospores in the diseased leaf debris in the soil and through the infected corms.

Storage rot

Causal organism: ***Aspergillus niger*** **Van Tiegham**
Botryodiplodia thebrome **Pat.**
Fusarium solani **(Mart.) Sacc.**
Rhizopus stolonifer **Sacc**
Sclerotium rolfsii **Sacc.**

Symptoms

Due to mechanical injury on the surface of the corms, there is attack by many pathogens or saprophyte which result rotting of edible potion of plant during storage.

Elephant foot yam (*Amorphophallus campanulatus* Blum)

FUNGAL

Collar rot

Causal organism: ***Rhizoctonia solani*** **Kuhn.**
Sclerotium rolfsii **Sacc.**

Symptoms

The pathogen mainly attacks the collar region and produces water soaked lesion. The whole plant soon turns yellow. A thick white mycelial growth can be seen on the affected portion. The stem shrinks and collapses due to rotting. Sclerotia (fruiting body) are also found on the mycelial growth. The pathogen is soil borne in nature.

VIRAL

Amorphophallus mosaic

Causal organism: Amorphophallus mosaic virus

Symptoms

The chief characterstic symptoms are mosaic mottling on the leaves. The disease causes more proliferation of lateral buds, seperation of buds from the mother corms and poor growth of roots. The infected plant produces small corms. The virus is transmitted by aphid *Myzus persici* and *Aphis gossypii*.

Yam (*Dioscorea alata* L.)

FUNGAL

Anthracnose or die back of yam

Causal organism: *Colletotrichum gleosporioides* Penz f.sp *alatae* Singh *et al*

Symptoms

The initially symptoms appears as brown spots on the leaves and stems. During favourable weather conditions, these spots coalesce and form bigger ones. The brown to black lesions on petioles cause premature defoliation. Light to dark brown acervuli of the fungus appears on these lesions during wet weather.

Cercospora leaf spot

Causal organism: *Cercospora contraria* H & P Syonodow
***Cercospora carbonacea* Miles**
***Cercospora dioscoreae* Ell. & Mart.**

Symptoms

Cercospora contraria produce symptoms as large grey with brown margins on the leaf. Clustetrs of conidiophores are very dense. The spots are nearly olive to light brown in coloure on lower leaf surface. *Cercospora dioscoreae* causes large angular, brown to black spots. *Cercospora carbonacea* causes large, angular, brown to black spots. On the lower surface of leaves, the spots are nearly olive colour.

Storage rot

Causal organism: *Botrydiplodia* spp
***Penicillium* spp**
***Aspergillus* spp**
***Fusarium* spp**

Symptoms

These fungi cause wet rot, soft rot or brown rot during storage due to mechanical injury on the surface of yam and cause considerable damage. It becomes unfit for human consumption.

VIRAL

Yam mosaic

Causal organism: Yam mosaic virus

Symptoms

The symptoms arecharacterized as leaf puckering, chlorosis and necrosis of vein on the surface. Leaf mottling is a common symptom. A minor retardation of infected plants was also observed (Plate 51).

SALAD CROPS

Lettuce (*Lactuca sativa* L.)

FUNGAL

Damping off

Causal organism: *Pythium ultimum* Trow.
Rhizoctonia spp Kuhn.

Symptoms

The pathogen attacks on the pre emergance stage of the plant and is characterized by rotting of seeds and seedling under the soil. Post emergance damping off includes water soaked lesions on the hypocotyls near the soil line. The lesion girdles the stem and finally plants topple and die. The fungi are soil inhabitant (Plate 52).

Fusarium wilt

Causal organism: *Fusarium oxysporum* f. sp. *lactucae*

Symptoms

The primary symptoms of include wilting of the plant. It is characterized as red-brown streak extending from the upper taproot into the cortex of the crown. Yellowing of leaves and a brown to black streaking of the foliar vascular tissue is often present. Infected plants may be stunted or fail to form a head. The cortex of the crown turns a reddish-brown in colour and vascular darkening extends into the root tissue on the affected side of the plant.

Leaf drop

Causal organism: *Sclerotinia minor* Jagg.
Sclerotinia sclerotiorum (Lib.) de Bary

Symptoms

These fungi infect lettuce and causing a soft, watery decay of the plant tissue under favourable conditions. The leaves wilt, shrivel and drop down rapidly. Both fungi

produce sclerotia which survive in soils for long periods of time in dry conditions. *S. sclerotiorum* can be easily diagnosed in the field when large, black sclerotia form in infected plant tissue on leaf tissue and soil surface. Sclerotia may also germinate directly in the soil and infect plants. The fungus is soil inhabitant.

Downy mildew

Causal organism: *Bremia lactucae* Reg.

Symptoms

Initial symptoms are pale yellow regions on the upper side of leaves. The infection spread upwards from lower leaves, the entire leaf surface covered by downy growth of fungus composed of conidiophore and conidia of the pathogen. Infected areas are limited by leaf veins. Infected tissue turns brown in colour. The chief mean of overwintering and oversummering is fungal oospores (Plate 53).

Grey mold

Causal organism: *Botrytis cinerea* Pers. ex Fr.

Symptoms

The stem at soil line shows brown necrotic lesion and often the leaves touching the soil are also infected. The entire leaf may be soon covered by the fungal growth under the favourable conditions. In dry weather, black dry decay occurs. Black coloured sclerotia are often seen on the older leaves. The fungus grows on dead and decaying plant refuse as a saprophyte. It also survives in form of sclerotia and on weed host.

Powdery mildew

Causal organism: *Erysiphe cichoracearum* DC

Symptoms

Initial signs are small tufts of fungal growth on upper or lower leaf surfaces. As disease develops, much of the leaf may become covered by the fungal hyphae, giving it a powdery or dusty appearance. Masses of spores, which are easily windborne produced in chains from the hyphae (Plate 54).

Anthracnose

Causal organism: *Marssonina panattoniana* (Berl) Magm

Symptoms

The disease initially appear as small spots on older leaves and progress to the younger leaves. The disease plant remains stunted and shows sick appearance. The spots enlarge and become brown. The necrotic centers of the spots may fall off giving it a shot hole look. The disease is dessiminated through infested soil or carried by rain splashes. The fungus is seed borne and persists in plant refuse left in the field.

BACTERIAL

Bacterial rot of lettuce

Causal organism : *Xanthomonas vitians* (Brown) Dows

***Pseudomonas marginalis* (Brown) Stapp**
***Pseudomonas. cichori* (Swing)**
Erwinia caratovora* (Jones) Bergey *et al.

Symptoms

It affects the lettuce during transit and marketing. There is slimy decay of large internal leaves, decaying tissues look like water soaked which soon become brown in colour.

VIRAL

Lettuce mosaic

Causal organism: Lettuce mosaic virus (LMV)

Symptoms

The primary symptoms on leaves show mottling. In severe infection, the plant fails to form head. Some times even when head is formed, it is irregular and leaves are lobed. It causes internal tip necrosis resulting rusty brown discolouration. The symptoms are more pronounced during wet and cloudy weather. Clearing of vein is a common symptom in young as well as old plant. The disease is seed borne and transmitted by aphid (*Myzus persicae).*

Lettuce big vein

Causal organism: Lettuce big vein virus

Symptoms

It is caused by a virus-like agent that causes a pronounced clearing of the chlorophyll next to major veins which is very prominent and leaves are held up to bright light. The symptoms appear in cool weather about one month after seeding. Big vein is transmitted by motile spores, zoospores of the soil borne fungus, *Olpidium brassicae* (Plate 55).

NONPARASITIC

Tip burn of lettuce

Physiological disorder (Calcium deficiency)

Symptoms

Symptoms appear in the form of dark brown spots near the leaf margin followed by marginal necrosis of leaves.

Celery (*Apium graveolens* L.)

FUNGAL

Damping off

Causal organism: *Pythium* spp

Symptoms

Infected seelings topple over anytime after emergence from soil. Infected tissue

becomes soft and water soaked. The stem becomes constructed at the base which results in collapse of the seedling. The pathogen survives in the soil in infected debris.

Fusarium yellow

Causal organism: *Fusarium oxysporum* f.sp *apii* (R. Nelson & Sherb) Snyder and Hans

Symptoms

The leaves of older plant turn yellow and drop. The whole plant turns of yellow coloured. On longitudinal splitting of the stem, browning of vascular bundle is seen. Root decay also takes place and finally plant dies. The fungus overwinters as chlamydospore and survives in the soil for many years.

Cercospora leaf spot

Causal organism: *Cercospora apii* Fres

Symptoms

The symptoms are noticed on both surface of the leaves, petioles and stems and appear as small yellow spots. In the severe infection, these spots enlarge coalesce with each other. Later on, the colour of these spots changes to grey and finally they become necrotic. The disease is seed borne and pathogen also overwinters in crop refuse.

Late blight or Septoria blight

Causal organism: *Septoria apii-graveolentis* Dorogen

Symptoms

Symptoms appear in the form of minute chlorotic spots which appear on the lower outer edge of the leave. Necrotic areas with definite margins appear in the center. The fruiting bodies are seen with the appearance of chlorosis till the outside margin of the necrotic area. The fungus survives and crop debris as well as on seeds.

Black crown rot

Causal organism: *Pseudomonas syringae* f.sp *apii* Jagg

Symptoms

The spots are water soaked, minute and yellow in colour. When they enlarge becomes light yellow. The spot has a reddish brown center with yellowish halo. After a number of spots appear on the leaf, the leaf finally dies. The diesease is disseminated by rain splashes. The bacterium is soilborne in nature.

VIRAL

Celery mosaic

Causal organism: Celery mosaic virus

Symptoms

Symptoms are characterized as leaf mottling and formation of leaf spot. The other strain of mosaic virus cause mottling and greyish colour of inner leaves. Leaflet turn fern like and growth becomes stunted.

LEAFY AND OTHER GREEN VEGETABLES

Spinach (*Spinacea oleracea* L.)

FUNGAL

Damping off

Causal organism: *Pythium* spp

Symptoms

Seedlings are attacked by the fungus at the ground level and are killed. The fungus is soil inhabitant.

White rust

Causal organism: *Albugo occidentalis* Wilson

Symptoms

The chief symptoms develop in the form of circular or irregular white pustules on the lower surface of the leaves. Yellow patches develop on the upper surface corresponding to each pustules of the lower surface.

Anthracnose

Causal organism: *Colletotrichum spinacicola* Chupp.

Symptoms

Symptoms initially appear as small, dark olivaceous or watersoaked spots develop on the leaves. These spots enlarge and give scorchy appearance. Eventually the spots coalesce and cause death of the entire leaf. Elongated greyish spots are abundantly formed on the seed stalks. The fungi are seed borne and pathogen also survives on the crop debris.

Downy mildew

Causal organism: *Pernospora spinaciae* Laubert

Symptoms

Light yellow area appears on the surface of leave and young plants become pale green, stunted and have crinkled leaves. The fungus perennates by mean of oospores.

Leaf spot

Cercospora leaf spot

Causal organism: *Cercospora beticola* Sacc.

Symptoms

Very small, circular to angular, greyish brown to dark olivaceous spots with a reddish brown margin are formed in the leaf. Small black stroma of the fungus develops in the center of the spots and produce clusters of conidiophores.

Phyllosticta leaf spot

Causal organism: *Phyllosticta chenopodii* Sacc.

Symptoms

Disease is characterized as circular and brown spots with reddish borders are formed on the leaves. Smaller black pycnidia are formed in the center of the spots.

BACTERIAL

Bacterial soft rot

Causal organism: *Erwinia caratovora* (Jones) Bergey *et al*

Symptoms

Watersoaked areas appear on broken or crumpled leaves. Symptoms develop when the leaves are tightly packed, not cleaned and aerated.

VIRAL

Mosaic and blight

Causal organism: Cucumber mosaic virus

Symptoms

Mottling of the young inner leaves is the initial symptom of the dsease. The mottling changes to yellow colour and finally the leaves are killed. The leaves curl and wrinkle before death.

Fenugreek (*Trigonella foenum-graecum* L.)

FUNGAL

Cercospora leaf spot

Causal organism: *Cercospora traversiana* Sacc

Symptoms

Symptoms appear in the form of brown elliptical or round spots with dark margin which later become a dark olive in colour and fungal growth appear in the center of the spot.

Coriander (*Coriandrum sativum* L.)

Stem gall of coriander

Causal organism: *Protomyces macrosporus* Unger

Symptoms

Disease is characterized as tumour like swelling appear on leaf veins, stalk, pedincle, stem as well as fruits. All galls look like a hanging in appearance. The lesions first seen as glossy then become rupture and rough. Disease appeares in excess of soil moisture and shaded condition. The pathogen mainly survives in seed as well as on soil.

Bell pepper or Sweet pepper (*Capsicum annum*)

FUNGAL

Damping-off

Causal organism: ***Pythium*** **spp**

Rhizoctonia solani **Kuhn**

Symptoms

Damping-off is a seedlings disease, older plants are susceptible than the young seedling. Pathogen attacks on the young plants as they are just emerging from the seed. The symptoms of preemergence damping-off are characterized as no seedling emergence. Damping-off in young, emerged, seedlings is seen as a toppling over of the seedlings as the root systems are destroyed by the fungi. The disease is more common where sanitation practices are poor. Pathogen survives in seed and soil.

Fusarium stem and fruit rot

Causal organism: ***Fusarium solani*** **Howard** ***et al***

Symptoms

The initial symptoms consist of change in colour from green to silver of outer leaves. The symptoms appear on the stem, nodes or wound site as a soft brown to dark brown sometime black lesion. Black water-soaked lesions may also develop around the calyx, eventually spreading down the sides of the fruit. Vascular discolurisation and cortical root rot were also osserved. Under conditions of high humidity the fungal mycelium is quite apparent on the lesions.

Grey mold

Causal organism: ***Botrytis cinerea*** **Pers ex Fr**

Symptoms

Grey mold is a common disease of greenhouse crops grown under conditions of high humidity and poor air circulation. The fungus enters the plant from wound sites and olive-green lesions develop that can eventually girdle the stem causing the plant death. Fruit infections commonly begins at the calyx or at wound sites.

Powdery mildew

Causal organism: ***Oidioopsis sicula scalia***

Tel: Leveillula taurica **(Lev) Arn.**

Symptoms

White powdery spots develops on the lower surface of the leaves, a slight chlorosis of the upper leaf surface is associated with the spots. The disease appear at the time of flowering at hot weather i.e. February to March.

Viral

Pepper mild mottle

Causal organism: Pepper mild mottle virus (PMMV)

Symptoms

As the disease progresses in the plants, the new growth can be distinctly stunted with a clear mosaic pattern of yellow and green. Colour streaking and green spotting are common symptoms develop on mature fruit. Fruits tend to have pointed ends and may

also develop sunken brown areas on the surface. Pepper mild mottle virus enters in the greenhouse primarily through infected seed, transplants plant sap and plant debris. Virus is easily spread the routine handling of the young plants especially at transplanting.

Tobacco mosaic

Causal organism: Tobacco mosaic virus (TMV)

Symptoms

The symptoms of infection first appear on the leaf as a mottling, chlorosis, curling and 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.

Tomato spotted wilt

Causal organism: Groundnut Bud Nurosis Virus

Symptoms

It becomes a significant problem in greenhouse pepper crops if the thrips vector is present. Symptoms of infection on the leaves include blackish-brown circular spots or tan spots bordered by a black margin. Orange to yellow spots surrounded by a green magin appears on the fruits.

Tomato mosaic

Causal organism: Tomato mosaic virus (TMV)

Symptoms

Disease is characterized as chlorosis, mottlimg, curling, distortation and dwarfing of leaves, flowers and entire plants. In some plants necrotic areas develop on the leaves.

NON PARASITIC

Blossom end rot

The disorder is associated with a number of environmental stress triggers as well as calcium deficiency. Symptoms of blossom end rot appear as soft spots on the fruit which develop into sunken tan-brown lesions with a very distinct border between affected and healthy tissue.

Sunscald

Symptoms

High temperature usually responsible for sunscald injury. Soft, tan coloured sunken lesions develop on fruit which are exposed to direct sunlight. The spot appears on the sun exposed side of fleshy fruit. These results in discolouration, water soaked appearance, blistering and dissication of the tissue beneath the skin which leads to the sunken area on the fruit surface.

Fruit cracks

Symptoms

This condition is characterized by the appearance of very fine, superficial cracks

on the surface of the pepper fruit which gives a rough texture to the fruit. The developments of these cracks are associated with sudden changes in the growth rate of the individual fruit.

Fruit splitting

Symptoms

The development of large cracks in the fruit is a direct response of high root pressure. Factors that contribute to the development of high root pressure directly impact fruit splitting. Ensure that optimal Vapour Pressure Deficit targets are met at all times.

Fruit spots

Symptoms

The appearance of small white dots below the surface of the pepper fruit is associated with excess calcium levels in the fruit and the subsequent formation of calcium oxalate crystals.

Misshapen fruit

Symptoms

The development of misshapen fruit is generally associated with sub-optimal growing conditions at flowering and pollination that result in poor flower development or poor pollination. Some of the common causes of misshapen fruit which include the temperatures being either too cool or too warm.

SOME OTHER VEGETABLES

Okra (*Abelmoscus esculentus* L.)

FUNGAL

Damping off

Causal organism: *Pythium* spp., *Rhizoctonia* spp.

Symptoms

Pathogen kills seedlings before or soon after they emerge. Pathogen develops a lesion near emerged seedling and attack tender stem which are in contact with the soil surface. The tissues beneath the lesion become soft due to which the seedlings collapse. There are some factors like cool, cloudy weather, high humidity, wet soils, compacted soil, and overcrowding especially favor development of damping-off. The pathogen is soil inhabitant in nature.

Fusarium wilt

Causal organism: *Fusarium oxysporum* f. sp. *vasinfectum* (Atkinson) Snyder and Hansen

Symptoms

Initially the plants show temporary wilting symptoms which later become permanent and progressive finally affecting the whole plant. The leaves of the affected plants show yellowing, loose turgidity and show drooping, finally death of the plant. In older plants,

leaves wilt suddenly and vascular bundles in the collar region become yellow or brown. The fungus attacks the root system and colonizes the vascular system. The fungus survives in form of chlamydospores in the soil.

Powdery mildew

Causal organism: ***Erysiphe cichoracearum*** **DC**

Symptoms

The pathogen mainly attacks on the older leaves and stems of plants. The disease symptoms appear as small, round, whitish spots on leaves and sometimes on the stems. The spots enlarge and coalesce rapidly and a white mass resembling talcum powder becomes evident on the upper surface of older leaves and other plant parts. Heavily infected leaves become yellow then become dry and brown.

Cercospora leaf spot

Causal organism: ***Cercospora abelmoschi*** **Ell. & Ev.**

C. malavensis **Stevans**

Symptoms

The fungus appears as shooty mold on the lower surface of leaves. Badly affected leaves roll, wilted and fall down. The pathogen survives through the conidia and stromata on the disease plant debris. *C. malavensis* causes brown, irregular spots and *C. abelmoschi* causes sooty black angular spots. The affected leaves roll, wilt and fall. The fungus survives on the diseased plant material. The disease causes severe defoliation during humid seasons.

VIRAL

Yellow vein mosaic

Causal organism: Yellow vein mosaic virus (YVMV)

Symptoms

This is the most important and destructive viral disease in okra. The pathogen attacks at all the stages of crop growth. The disease is transmitted by white fly (*Bemisia taleaci*) and leafhopper (*Empoasca devastans*). The characteristic symptoms of the disease are a homogenous interwoven network of yellow veins enclosing islands of green tissues. Initially infected leaves exhibit only yellow coloured veins but in the later stages, the entire leaf turns completely yellow. In extreme cases, the infected leaf becomes totally light yellow or cream coloured and there is no trace of green colour (Plate 57). Plants infected in the early stages remain stunted. The fruits of the infected plants exhibit pale yellow colour, deformed, small and tough in texture.

Enation leaf curl of okra

Causal organism: Enation leaf curl virus

Symptoms

The disease symptoms prominently appear on the lower surface of the leaf as small, pinhead enations which later become warty and rough textured. Size of the leaf is reduced.

The chief characteristic symptoms of the disease are twisting of the main stem and lateral branches along with enations. Entire plant appears to be creeping on the soil surface because of bending of the plants. The leaves become thick and leathery in structure. In case of heavy infection the newly emerged leaves also exhibit bold enations, thickening and curling. Fruits produced on the infected plants are few and deformed.

NEMATODES

Root knot nematodes

Causal organism: ***Meloidogyne incognita***

Meloidogyne javanica

Symptoms

Symptoms are reduced growth and fewer, small, pale green or yellowish leaves that tend to wilt in warm weather. Disease appears on the roots in form of knots or galls. The plant bears spherical and elongated gall which vary in size from very small to very large. The plant remains stunted and bears less fruit.

Asparagus (*Asparagus officinalis* L.)

FUNGAL

Fusarium wilt

Casal organism: ***Fusarium oxysporum*** **Schlechtend ex fsp** ***asparagi*** **Cohen**

Symptoms

Disease is characterized as yellowing, stunting of seedling and vascular system becomes discoloured. Discolouration of vascular bundles of root and crown are common on mature plant. Elliptical red brown lesion may appear on the stem near the soil line. Seed infection mainly occurred during the seed harvesting process by infecting soil adhering to fallen berries.

Rust

Causal organism: ***Puccinia asparagi*** **DC**

Symptoms

The browning or reddening of smaller twigs and needles are initial symptoms of this disease. The red colour is due to the stem and needles being covered with small pustules. The postules release dusty cloud when disturbed. These red postules are replaced by dark coloured when season advances.

Cercospora blight

Causal organism: ***Cercospora asparagi*** **Sacc**

Symptoms

Presence of oval to elliptical ash grey lesion on stem and branches are the charateristic symptoms of the disease. The center of the lesion is tan to grey border by white brown margin. In severe infection defoliation occurs. The conidia are carried by wind or water splashes.

Globe artichoke (*Cynara scolymus* L.)

FUNGAL

Powdery mildew

Causal organism: *Leviellula taurica* (Lev.) Arnaud

Symptoms

The fungus mainly produces a white talcum which covers the lower surface while the corresponding upper surface of the leaves turn yellow. The fungal spore germinates when the humidity is low and weather is warm. The fungus spores are wind disseminated.

Ramularia leaf spot

Causal organism: *Ramularia cynarae* Sacc

Symptoms

The fungus mainly attacks the foliage and not the head. The dsease appears as small grey spots and finally the entire leaf turn necrotic.

Black rot

Causal organism: *Ascochyta cynarae* Maffei

Symptoms

Disease is characterized as greyish, white irregular spot with slight depression on the upper surface of leaves. The discolouration usually begins at the tip of the outer bracts and spreads downwards gradually. Finally the entire head is infected. The black pycnidia containing spores develop on older spots. The disease is seed borne. The pathogen overwinters on previous crop stubble and other plant debris.

CONCLUSION

Although a wealth of information has been generated on disease management of vegetable crops in India, even after lot more needs to be done for its effective management. The four basic requirements for management of plant disease are; use of clean and healthy seeds field sanitation or soil should be free from pathogen, prevention of entry and infection by pathogen in a standing crop and precaution during harvesting and storage of the produce. An ideal schedule for controlling a disease is to integrate measures covering these four requirements. Usually an integrated programme is aimed against all disease affecting a crop. Sometime it is aimed against one or two most destructive diseases of the crop. Now new concept is emerging ie multiple disease management. There is need to work on host resistance breeding for cultivars with field resistance, which would be last longer. There is need to exploit durable resistance through biotechnology. Plant Pathologists have learnt to use the modern tools of genetic engineering & tissue culture in management of plant disease. It is possible to isolate particular gene from one organism, insert them into the genome of another organism and make them to express at right time. This is more so in the context of developing countries where capacity of the vegetable growers to purchase and apply chemicals is low. Despite of all efforts in developing

resistant varieties, use of chemical would remain the necessary evil. However developing need can enhance efficacy based application system.

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Plate 1 Symptoms on foliage of potato

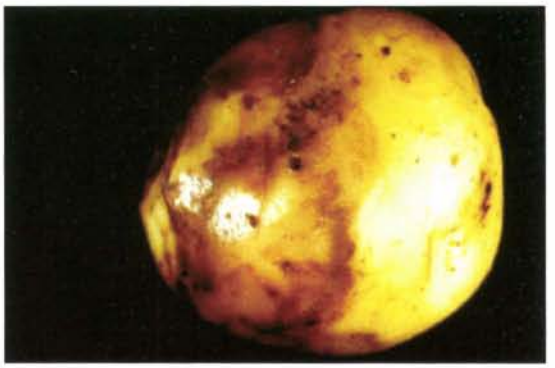


Plate 2 Late blight of potato

Plate 3 Early blight of potato

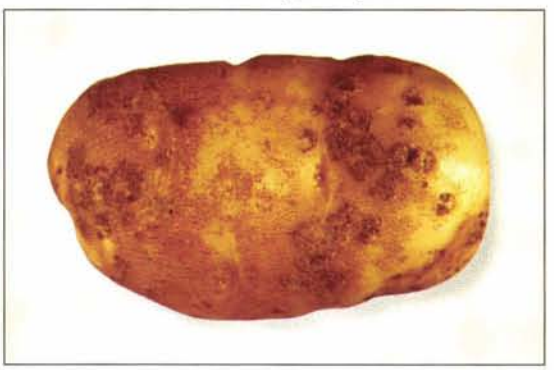


Plate 4 Scab of potato

Plate 5 Potato leaf roll

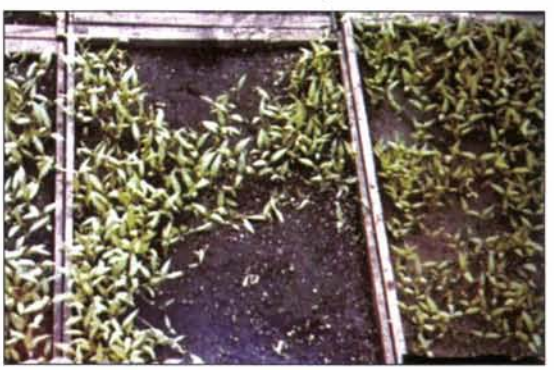


Plate 6 Damping off of tomato

Plate 7 Buckeye rot of tomato

Plate 8 Early blight of tomato

Plate 9 Bacterial spot of tomato

Plate 10 Bacterial wilt of tomato

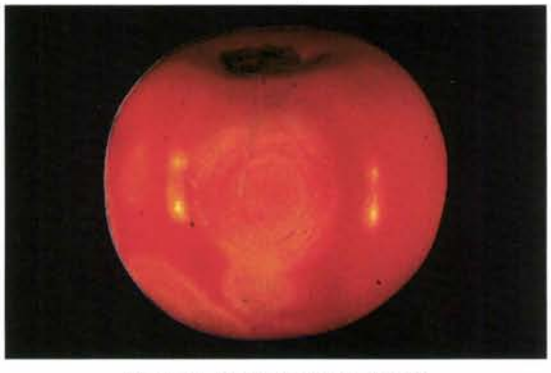


Plate 11 Tomato spotted wilt

Plate 12 Sun scald of tomato

Plate 13 Phomopsis blight of egg plant

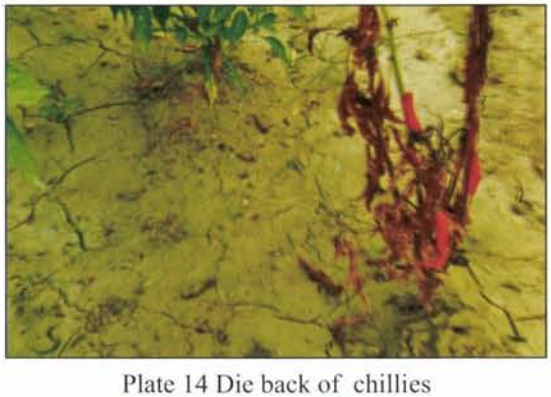


Plate 14 Die back of chillies

Plate 15 Cercospora leaf spot of chillies

Plate 16 Bacterial leaf spot of chillies

Plate 17 Mosaic of chillies

Plate 18 Pythium aphanidermatum fruit rot of cucurbits

Plate 19 Pythium fruit rot of cucurbits

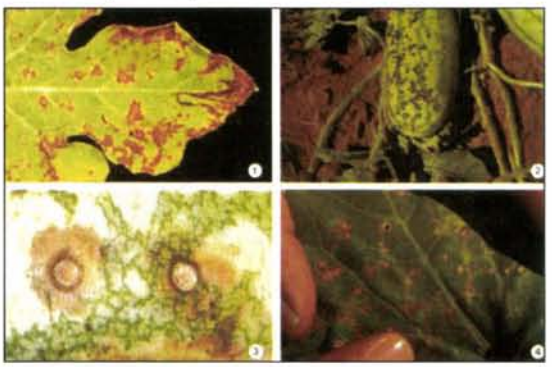


Plate 20 Anthracnose of cucurbits

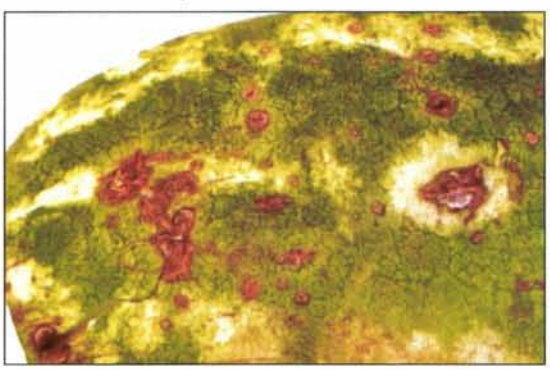


Plate 21 Anthracnose of cucurbits

Plate 22 Powdery mildew early symptoms of cucurbits

Plate 23 Powdery mildew late symptoms of cucurbits

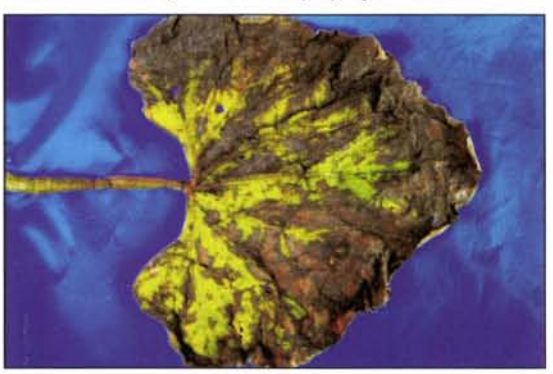


Plate 24 Downy mildew cucumber

Plate 25 Cucumber mosaic virus

Plate 26 Powdery mildew infection on beans

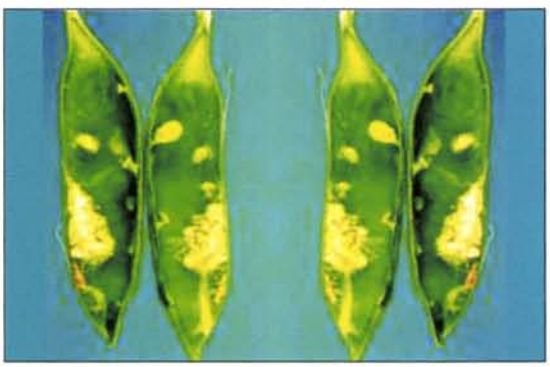


Plate 27 Downy mildew inside the pod.

Plate 28 Fusarium root rot of beans

Plate 29 White mold infection on beans

Plate 30 White mold infection on beans

Plate 31 White mold infection on beans

Plate 32 Angular leaf spot on beans

Plate 33 Angular leaf spot of beans

Plate 34 Angular leaf spot of beans

Plate 35 Angular leaf spot of beans

Plate 36 Angular leaf spot of beans

Plate 37 Rust of beans

Plate 38 Bacterial blight of beans

Plate 39 Mosaic virus of beans

Plate 40 Purple blotch of onions

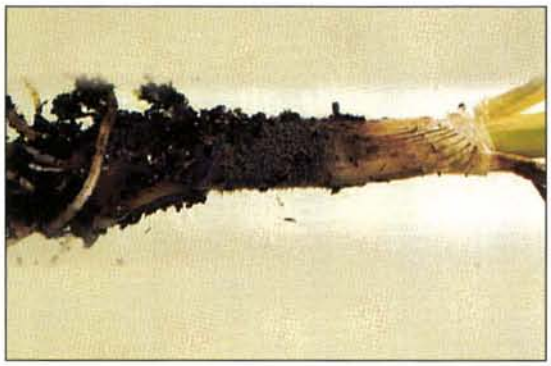


Plate 41 Botrytis leaf spot of onion

Plate 42 Fusarium basal rot of onions

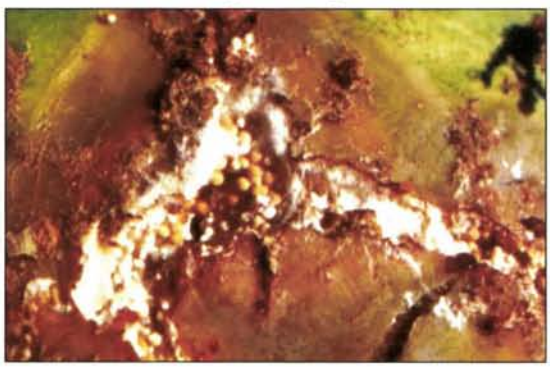


Plate 43 Sclerotia of southern blight on onions

Plate 44 Onion smut

Plate 45 Onion smudge

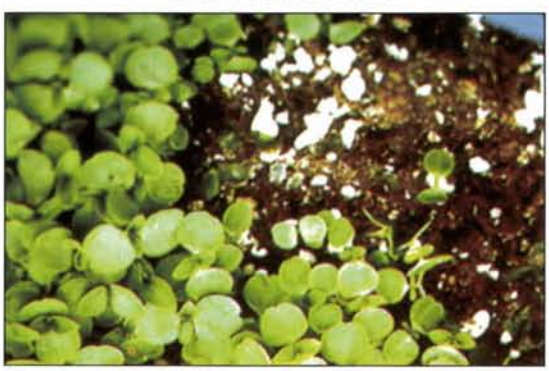


Plate 46 Damping off of cabbage

Plate 47 Sclerotinia rot of cabbage

Plate 48 Alternaria leaf spot of cauliflower

Plate 49 Aster yellows on carrot

Plate 50 White rust of radish

Plate 51 Mosaic of yam

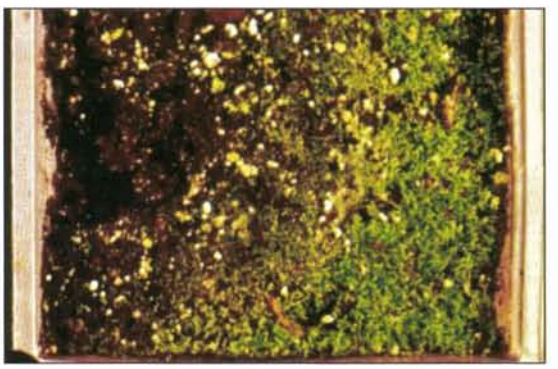


Plate 52 Damping off of lettuce

Plate 53 Downy mildew on lettuce

Plate 54 Powdery mildews of lettuce

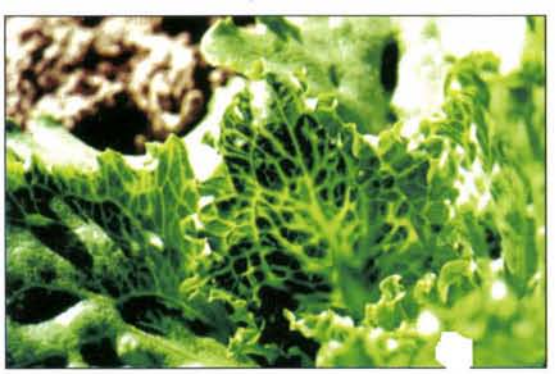


Plate 55 Lettuce big vein

Plate 56 Yellow vein mosaic of okra

Plate 57 Green house

Plate 58 Tricoderma treated veg seedlings 2

4

BIOMANAGEMENT : MICROBIAL PESTICIDES

PRINCIPLES OF BIOLOGICAL CONTROL

Biological control of the plant pathogens naturally occurs at some level in all agricultural ecosystems, sometimes to a degree where symptoms of disease are noticeably reduced compared to ecosystem experiencing similar disease pressure. Research interest in dissecting the complexity of the interactions that takes place in naturally occurring biological control systems and utilizing specific antagonistic microorganisms or agricultural practices so as to purposefully recreate a pathogen-suppressive microbial environment has increased in recent years. Biomanagement is synonym of biological control which includes various components and parameters.

Many definitions have been proposed for biological control. The term 'Biological Control' was coined by the late Harry Smith of the University of California, who defined it as the suppression of insect populations by the actions of their native introduced enemies. There have been debates regarding the scope and definition of biological control ever since, mainly to accommodate the technological advances in the tools available for pest management. The definition presented by Van Drieschce 1996, the use of parasitoid, predator, pathogen, antagonist, or competitor populations to suppress a pest population making it less abundant and thus, less damaging than it would otherwise be, appears to convey the current thinking on biological control by those researchers involved in insect research.

In their earlier definition of biological control, Baker and Cook (1974) described it as the reduction of inoculum density or disease producing activities of a pathogen or a parasite in its active or dormant state, by one or more organisms, accomplished naturally or through manipulation of the environment, host or antagonist, or by mass introduction of one or more antagonists. This concept is closely related to the Systemic acquired

resistance concept where host is the target. The manipulation of environment reflects the use of various cultural practices or using tolerant cultivars or in other words it does not allow the bioagent to be used singly. This definition was subsequently modified to understand the reduction in the amount of inoculum or disease-producing activity of a pathogen accomplished by or through one of more organisms other than man. This definition clearly widens the scope of biological control by allowing the researchers to use microbial, plant products, cultural practices into a biological control system. These are perhaps the most widely quoted and accepted definitions of biological control. As used in plant pathology, the term "biological control" commonly refers to the decreased inoculum or the disease producing activity of a pathogen accomplished through one or more organisms, including the host plant but excluding man. (Baker,1987). Biological control of the plant pathogens naturally occurs at some level in all agricultural ecosystems, sometimes to a degree where symptoms of disease are noticeably reduced compared to ecosystem experiencing similar disease pressure. Research interest in dissecting the complexity of the interactions that takes place in naturally occurring biological control systems and utilizing specific antagonistic microorganisms or agricultural practices so as to purposefully recreate a pathogen-suppressive microbial environment, has increased in recent years.

Some times later, the U.S. National Academy of Sciences introduced some modifications to the definition, referring to biological control as the use of natural or modified organisms, genes or gene products to reduce the effects of undesirable organisms and to favour desirable organisms such as crops, beneficial insects and microorganisms, obviously, due consideration has been given to the advances by the advent of molecular biology to plant pathology and to research in biological control.

There have been other recent definitions, many of which still reflect the basic idea presented in the classical definitions of biological control. According to Shurtleff and Averree (1997), biological management or control refers to disease or pest control through counter balance of microorganisms and other natural components of the environment. It involves the control of pests (bacteria, fungi, insects, mites, nematodes, rodents, weeds, etc.) by means of living predators, parasites, disease-producing organisms, competitive microorganisms and decomposing plant material, which reduces the population of the pathogen. This definition has widened the scope of the use of bioagents in Integroted Pest Management systems where we need to apply and protect the crop as a whole and therefore a single application or approach does not help the researcher in using the bioagents. Agrios (1997) defined biological control as the total or partial destruction of pathogens and management of host. The modifications introduced to the basic definition of biological control by different workers indicate its changing scope and perspective. This is largely attributed to the insights obtained by the use of various molecular and biochemical tools for the study of this hitherto poorly understood phenomenon involving interactions within a multicomponent system. Therefore, biological control of plant pathogens has now emerged as a broad concept, and encompasses several mechanisms. This concept itself includes both direct and indirect effects, due either to introduced antagonists or manipulation of existing populations to reduce disease. (Fig. 1)

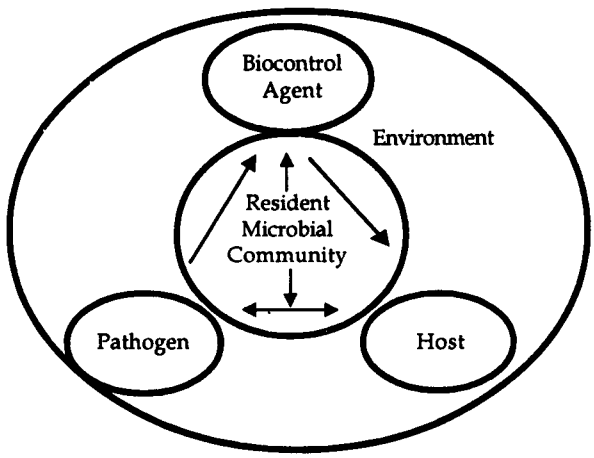


Figure 1 : Ecological Interaction Associated with Biological Control

(A) DIRECT- INTRODUCTION OF ANTAGONISTS

The main means of controlling pests like insects, fungi, bacteria or weeds have been the use of chemicals. The problems with chemicals are:

(i) they are harmful to wildlife, environment, humans due to the accumulation of toxic residues

(ii) many of the fungicide and insecticides are expensive

(iii) pesticide resistance develops—especially in insects and pathogens

(iv) adverse effects on beneficial species (honey bees) and non-target animals

(v) secondary pest outbreaks (previously innocuous species increase in number)

Potential agents for biocontrol activity are rhizosphere-competent fungi & bacteria which, in addition to their antagonistic activity are capable of inducing growth responses by either controlling minor pathogens or by producing growth-stimulating factors.

Before biocontrol can become important component of plant disease management, it must be effective, reliable, consistent and economical to meet these criteria, superior strains, together with delivery systems that enhance biocontrol activity, must be developed.

Existing biological control attributes can be enhanced by improving existing, known biological agents, with genetic manipulation. Genetic manipulations of biocontrol agents not only can enhance their activity, but also can expand their spectrum.

The growing interest in biocontrol with micro-organisms is also a response to the new tools of biotechnology plants and micro-organisms can now be manipulated to deliver the same mechanism of biological control, as has been done for the production of the delta endotoxin encoding gene transferred from *Bacillus thuringiensis* to plants to control insect pests. We can now think of micro-organisms with inhibitory activity against plant pathogens as potential sources of genes for disease resistance.

The successful control by biological means in the phylloplane that have been reported involve mainly rusts, powdery mildews and diseases caused by following genera of pathogens : *Alternaria, Epicoccum, Sclerotinia, Spetoria, Drechslera, Venturia, Plasmopara, Erwinia and Pseudomonas.* Good soil biocontrol systems have been reported for species of *Fusarium, Sclerotium, Sclerotinia, Pythium and Rhizoctonia.*

The following biocontrol agents have already been registered; *Agrobacterium radiobactor* against crown gall (USA, Australia, NZ); *Bacillus subtilis* for growth enhancement (USA); *Pseudomonas fluorescens* against bacterial blotch (Australia); *Pseudomonas fluorescens* for seedling diseases (USA); *Peniophora gigantea* against *Fommes annosus* (UK); *Pythium oligandrum* against *Pythium spp.* (USSR); Trichoderma viride against timber pathogens (Europe); *Trichoderma spp.* for root diseases (USSR); *Fusarium oxysporium* against *Fusarium oxysporum* (Japan); *Trichoderma harzianum* against root diseases (USA); *Gliocladium virens* for seedling diseases (USA); *Trichoderma harzianum*/Polysporum against wood decay (USA).

Trichoderma spp. act against a range of economically important aerial & soilborne plant pathogens. They have been used in the field & greenhouse against silver leaf on plum, peach & nectarine; Dutch elm disease on elm's honey fungus (*Armillaria mellea*) on a range of tree species; and against rots on a wide range of crops, caused by *Fusarium, Rhizoctonia,* and *Pythium,* and *Sclerotium* forming pathogens such as *Sclerotinia & Sclerotium.* In many, experiments, showing successful biological control, the antagonistic *Trichoderma* is the major mycoparasite.

From recent work, it appears that mycoparasitism is a complex process, including several successive steps. The first detectable interaction shows that the hyphae of the mycoparasite grows directly towards its host. This phenomenon appears a chemotropic growth of *Trichoderma* in response to some stumuli in the hosts's hyphae or toward a gradient of chemicals produces by the host.

When the mycoparasite reaches the host, its hyphae often coil around it or are attached to it by forming hook like structures. In this respect, production of appressoria at the tips of short branches has been described for *T. hamatum & T. harzianum.* The interaction of *Trichoderma* with its host is specific. The possible role of agglutinins in the recongnition process determining the fungal specificity has been recently examined. Indeed, recognition between *T. harzianum* & two of its major hosts, *R. solani & S. rolfsii,* was controlled by two different lectins present on the host hyphae. *R. solani* carries a lectin that binds to galactose & fractose residues on the Trichoderma cell walls. This lectin agglutinates conidia of a mycoparasitic strain of *T. harzianum,* but did not agglutinate two non-parasitic strains.

This agglutinin may play a role in prey recognition by the predator Moreover, because it does not distinguish among biological variants of the pathogen, it enables the *Trichoderma* species to attack different *R. solani* isolates. The activity of a second lectin isolated from S. rolfsii was inhibited by d-glucose or d-mannose residues, apparently present on the cell walls of *T. harzianum.*

Following these interactions the mycoparasite sometime penetrates the host mycelium, apparently by partially degrading its cell wall Microscopic observations led to the

suggestion that *Trichoderma* spp. produced & secreted mycolytic enzymes responsible for the partial degradation of the host's cell wall.

The complexing & diversity of the chitinolitic system of *T. harzianum* involves the complementary modes of action of six enzymes, all of which might be required for maximum efficiency against a broad spectrum of chitin-containing plant pathogenic fungi.

The level of hydrolytic enzymes produced differs from host-parasite interaction analyzed. This phenomenon correlates with the ability of each *Trichoderma* isolate to cotntrol a specific pathogen. It is considered that mycoparasitism is one of the main mechanisms involved in the antagonism of *Trichoderma* as a biocontrol agent.

The process apparently includes :

(1) chemotropic growth of *Trichoderma,*

(2) recognition,

(3) secretion of extracellular enzymes,

(4) hyphae penetration, and

(5) lysis of the host.

The involvement of volatile & nonvolatile antibiotics in the antagonism by *Trichoderma* has been proposed. Indeed some isolates of *Trichoderma* excrete growth-inhibitory substances. Thus, the biocontrol ability of *Trichoderma* strains is most likely conferred by more than one exclusive mechanism. In fact, it seems advantageous for a biocontrol agent to suppress a plant pathogen using multiple mechanisms.

TABLE 1

Important biocontrol agents against different pests

Type of control	Examples
Insect control	
Bacteria	*Bacillus thuringiensis,B.sphaericus,B.Popilliaee,Serratia entomophila*
Viruses	Nuclear Polyhydrosis viruses , Granulosis viruses, non occulated baculoviruses
Fungi	*Baeveria, Metarhizium Entomophaga, Zoophtora, Paecilomyces, Normurea*
Protozoa	*Nosema, Thelohania ,Vairimorpha*
Entomopathogenic nematode	*Steinernema , Heterorhabditis, Romnomermis*
Others	Pheromones, parasitoids, predators, microbials by products
Weeds controls	
Fungi	*Alternaria, Colletototrichum*
Bacteria	*Xanthomonas*
Plant disease controls Nematode trapping fungi	

Contd...

...Contd.

Type of control	Examples
Competitive inoculants Compost, soil inoculants	*Arthrobotrytis*
Plant Disease control Bacteria	*Agrobacterium radiobacter, Bacillus spp , Burkholderia cepacia, Pseudomonas* spp., *Streptomyces* spp
Fungi	*Ampelomyces quisqualis,· Candida oleophila, Coniothyrium minitans,· Gliocladium* spp.,· *Myrothecium verrucaria* (killed),· *Paecilomyces lilacinus,· Phlebia gigantean,· Pythium oligandrum Trichoderma harzianum, T. viride, T. hamatum, Aspergillus niger,* non pathogenic *Fusarium.*

BIOPESTICIDES

Types of biopesticides

Microbial pesticides consist of a microorganism (eg. A bacterium, fungus, virus, or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest(s). For example, there are fungi that control certain weeds, and other fungi that kill specific insects.

The most widely used microbial pesticides are subspecies and strains of *Bacillus thuringiensis*, or Bt. Each strain of this bacterium produces a different mix of proteins, and specifically kills one or a few related species of insect larvae. While some Bt's control moth larvae found on plants, other Bt's are specific for larvae of flies and mosquitoes. The target insect species are determined by whether the particular Bt produces a protein that can bind to a larval gut receptor, thereby causing the insect larvae to starve. Trichoderma spp. are other set of microbes which have widely used against defferent pathogens.

Plant pesticides are pesticidal substances that plants produce from genetic material that has been added to the plant and also from the plant extracts. For example, scientists can take the gene for the Bt pesticidal protein and introduce the gene into the plants own genetic material. Then the plant, instead of the Bt bacterium, manufactures the substance that destroys the pest. Both the protein and its genetic material are regulated by EPA; the plant itself is not regulated.

Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances, such as insect sex pheromones, which interfere with mating, as well as various scented plant extracts that attract insect pest to traps. Because it is sometimes difficult to determine whether a substance meets the criteria for classification as a biochemical pesticide, EPA has established a special committee to make such decisions.

Advantages of biocontrols

- Biocontrols help reduce the use of chemical-based fungicides.
- They help reduce risk of developing pathogen resistance to traditional chemicals.
- In most cases, they are safer to use.

- They tend to be more stable than chemical pesticides if stored properly.
- In most cases, they have lower restricted-entry interval (REI) times.
- They are less phototoxic.

Advantages of biopesticides

- Biopesticides usually are inherently less harmful than conventional pesticides.
- Biopesticides generally affect only the target pest and closely related organisms, in contrast to broad-spectrum conventional pesticides that may affect organisms as different as birds, insects, and animals.
- Biopesticides often are effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides.
- When used as a component of Integrated Pest management (IPM) programs, biopesticides can greatly decrease the use of conventional pesticides, while crop yields remain high.

Keys to success

For any biological control agent to work, two simple rules must be followed:

1. All of these products must be used in conjunction with standard disease cultural controls.
2. All of these products must be applied before disease onset. They will not rescue plants that are already infected.

Some criteria for the development of ideal biocontrol product include:

1. Biocontrol products must have a relatively wide spectrum of efficacy.
2. The efficacy of the bioproducts must be high, consistent and reliable.
3. Biocontrol products also must meet the acceptable standards for environmental and toxicological safety.
4. The bioproducts must have acceptable shelf life without special storage requirements.
5. Manufacture of the biocontrol products also must be cost effective and provide consistent product quality.
6. Thorough understanding of mechanism (s) of action and ecological competence of the byproducts must be made to assure an efficacious product.
7. Some criteria must be developed that accurately predicts, when a crop response can be expected by particular bioproduct and also when none will occur, to prevent its use in non responsive locations.
8. The application of the biocontrol products should be easy, possible with existing plant protection equipments.
9. Biocontrol bioproducts also must be highly compatible with cultural and chemical control strategies.
10. A bioproduct must be compatible with control practices for other pests and with cultural practices used in crop production.

Bioformulations

The bioformulation of antagonists with optimum biocontrol potentiality should possess several desirable characteristics such as ease for preparation and application, stability, adequate shelf life and low cost. The biomass produced is separated by filtration or centrifugation, then be dried and milled prior to its incorporation into dusts, granules, pellets, wettable form or emulsified liquid. The drying process may influence the viability of propagules in biomass. The *Trichoderma* propagules survived differently in three drying processes i.e. pan drying, spray drying and lypophilized. Viability was maximum in pan drying and was least in lyophilized process. A number of ***bioformulations*** are marketed in developed and developing countries for the management of plant diseases (Table 2). Even in Indian market now days, several *Trichoderma and bacteria based* bioformulations are available. At present, total production of biofungicides in India is 1-2% of the total pesticide production. Availability of *Trichoderma* based bio-pesticides in India is over 500 tonnes and main constraints are quality and stability. It is estimated to increase these up to 15-20 per cent within a decade or so.

TABLE 2

Commercial microbial biofungicides available in world market for the management of plant diseases

Product	Antagonist	Country	Target pathogen
1	2	3	4
Contans	*Coniothyrium minitans*	Germany	*S. sclerotiorum ,S. minor*
KONI	C.minitens	Hungary	*S. sclerotiorum ,S. minor*
Biofox C	*Fusarium oxysporum*	Italy	*Fusarium oxysporum, Fusarium moniliforme*
Fusaclean	*F.oxysporum*	France	*Fusarium oxysporum*
SoilGard	*Gliocladium virens*	USA	*Pythium, Rhizoctonia, Fusarium*
Primastop	*G.catenulatum*	Finland	*Pythium, Rhizoctonia, Botrytis*
Polygandron	*Pythium oligandrum*	Slovak	*Pythium ultimun*
Bio-fungus	*Trichoderma* spp.	Belgium	*Sclerotinia, Phytophthora,*
Binab-T	*T.harzianum, T.polysorum*	Swedon,	*Pythium, Rhizoctoni*
Root Shield	*T. harzianum*	USA	*Fusarium*
Supresivit	*T.harzianum*	Denmark	*Pythium, Rhizoctonia,Fusarium*
T22G, T22	*T.harzianum*	USA	-do-
Trichodex	*T.harzianum*	Israel	*Botrytis, Monilia, Downy*
MTR-35			*mildews, Rhizopus, Sclerotinia*
Root Pro			
Trichoderma 2000	*Trichoderma* spp.	Israel	*Rhizoctonia, Sclerotinia,Pythium*

Contd...

1	2	3	4
Trichopel,	*T.harzianum*	New Zealand	*Armillaria, Fusarium,* Trichodowels, & *T.viride* *Phytophthora, Pythium, Rhizoctonia*
Protus WG	*Talaromyces flavus*	Germany	*Rhizoctonia, Verticillium*

TABLE 3

Commercial microbial biofungicides available in Indian market for the management of plant diseases

Product	Bioagents	Developing agency
Fungal	*T.viride*	Anu Biotech.
Trichogaurd	*T.viride*	Int .Ltd. Faridabad
Funginil	*T.viride*	Crop Health biproduct Research Centre Gaziabad
Ecofit	*T.viride*	Hoechest and Shering Agr Evo Ltd., Mumbai
Bioderma	*T.viride*	Biotech International Ltd New Delhi
Ecoderma	*T.viride &T. harzanium*	Margo. Biocontrol Pvt Ltd New Delhi
Defence -SF	*T.viride*	Wockhardt Life Science Ltd Mumbai
Tricho-X	*T.viride*	Excel Industries Ltd Mumbai
Bioguard	*T.viride*	Krishi Rasayan Export Pvt , Ltd . Solan (H.P.)
Biocon	*T.viride*	Tocklai Experimental Station Tea Research Association Johrat. Assam
Biocure -F	*T.viride*	T. Stanes Company Ltd, Coimbatore
Kalisena SL	*Aspergillus niger*	Cadila Pharmaceuticals Ltd Ahmedabad
Kalisena SD	*AN-27*	
Bacterial		
Biotok	*Bacillus subtilis*	Tocklai Experimental Station Tea Research Association Johrat. Assam
Biocure-B	*Pseudomonas fluorescence*	T. Stanes Company Ltd, Coimbatore
Bioshield	*Pseudomonas fluorescence*	Anu Biotech Int. Ltd. Faridabad

Disadvantages of biocontrols

Biocontrols tend to be more difficult to implement compared to chemicals.

- In most cases, they have a narrower target range.
- These products do not eradicate the pathogen or rescue the host from infection

- They may have a shorter shelflife than chemical controls if they are not stored properly
- In most cases, biocontrols are more expensive.
- They may not be compatible with other chemical fungicides and bactericides.
- The above features which are consedered to be disadvantages leads futher scope of study, and can be improvised before the development of bioformulation.

Selection of effective strains

The growing concerns in recent years about the environment coupled with lack of viable solutions for soil and foliar pathogens taking heavy tolls on crops offer the basic impetus for research and development. In the present times, biological control is certainly going to become a mainstay in commercial agriculture. Differences in effectiveness and reliability of strains may be encountered between field trials and investigators. If such findings are neglected, the probability of success of a final product be in a jeopardy. The BCAs exhibit different modes of action, and hence a good testing program should elucidate all the mechanisms involved in the biocontrol activity of the BCA. The expression of biocontrol is manifested in terms of rhizosphere competence, suppression of pathogens, tolerance to pesticides, competitive saprophytic ability, adaptability to environment etc. These traits are used for establishment of BCAs but before that selection technique for testing or efficacy of BCAs at host pathogen interface is a priority. Therefore, development of protocols for rapid and differential detection of plant pathogens and BCAs in the host system that facilitates reliable comprehensive testing of BCAs is our priority. We developed protocols for evaluating different isolates of Trihoderma. Twelve isolates of *Trichoderma* spp. including eight of *Trichoderma harzianum* and four of *T. viride* were evaluated for developing methods for screening antagonists against multiple pathosystem (Table 4, 5 and 6). Besides using dual test, the isolates were rigorously tested by using their toxic culture filtrate against phytotoxic culture filtrate of ten pathogens to find out the possible detoxification of several plant pathogens namely *Colletotirchum capsici, Sclerotinia sclerotiorum, Pythium aphenidermatum, Fusarium oxysporum* f.sp *lycopersici, Alternaria brassisicola, A.solani, A. alternata, Phomopsis vexans, Rhizoctonia bataticola* and *Rhizoctonia solani* isolated from chilli, cauliflower, tomato and brinjal plants. The *Trichoderma* spp. isolates were grown on a medium containing the above mentioned pathogen toxins at different concentration (Table 6) (Sharma and Durega 2004). These treated toxins were tested for its phytotoxic activity using symptom bioassay on their respective host plant leaves/seedling. *Trichoderma* treated phytotoxins exhibit very less symptom development in comparison to pure phytotoxin. It was observed that Th3, Th10, Th30, Th31 and Th32was found effective even at 1:3 ratios of *Trichoderma* metabolites and phytotoxin to reduce the diseases symptom on leaves and seedlings. The result shows that the effective isolates possessing the biocontrol characteristic cause detoxification of different pathogen toxins, which is one of the major pathogenicity determinants of the infection by the pathogen. This process protects plants from pathogen infection due to development of resistant/hypersensitive reaction. The *T. harzianum* metabolites were further characterized and chemically identified. Out of isolated 13 metabolites 6-pentyl-μ-pyrone was found to possess fungicidal activity

(Fig. 4). The medium containing the active metabolite reduced the growth of almost all the pathogen tested, EC_{50} ranging to 279.75 - 1107.07 ppm. These isolates were also screened against the commonly used pesticides i.e. benomyl, carbendazim, thiram, captan, mancozeb, iprodione, imidacloprid, chlorpyriphos, and pendamethalin and evaluated in terms of sensitivity EC_{50} scale using three scales (i) low risk pesticide (> 100µg/ml) (ii) medium risk (10 -100 µg /ml) and (iii) high risk (0.1-10 µg/ml) based on growth and sporulation intensity and categorized as follows, low risk pesticides captan and mancozeb, medium risk benomyl, iprodion, thiram, pendimethalin and, high risk carbendazim and chlorpyriphos. The reduction in the sporulation intensity was observed at EC_{50} level as compared to the required ideal cfu which is generally 4 - 8 x 10^8 The range of EC_{50} sporulation intensity to (0.5 - 1.15at 10^6 dilution). In the category medium risk pesticides range of sporulation intensity was (2-10 at 10^6) and in low risk sporulation intensity was above 10x10^6 (Table 7). The range of sporulation intensity of all the isolates differed against the EC_{50} values, which clearly exhibits the varied potential of the isolates in their sensitivity towards the pesticides (Sharma and Dureja 2004). These isolates are also effective in increasing growth performance (Table 8) which is an added advantage of using bioagents.

TABLE 4

Mix inoculation of different concentration of phytotoxin and *Trichoderma harzianum*,(Th3) toxic metabolites inoculated at same time on

Fusarium solani	*Pythium aphenider matuim*	*Sclerotinia sclerotiorum*	*Sclerotium rolfsi*	*R.bataticola bataticola*	*Rhizoctonia solani*
Seedling	Seedling	Seedling	Seedling	Seedling	Seedling
+	++	+	++	+	++
–	+	–	+	–	+
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–

Where, 0 = healthy, + = a 0.5 cm lesion on the seedling, ++ = more than two lesions on a seedling , +++ = 25-50% stem girdled or damped off, ++++ = more than 50 % blackened area, +++++ = wilted/ dead

TABLE 5

Symptom bioassay of effect of mixed inoculation of phytotxin of pathogens and *Trichoderma* metabolites on their host

P. aphenid ermatum	*S. scleroti orumm*	*S. rolfsii*	*R. bataticola*	*R. solani*	Dilution concentrations	*Alternaria alternata*		*Alternaria brassisicola*		*Colletotrichum capsici*		*Phomopsis vexans*	
SL	SL	SL	SL	SL	Toxin+Th	Young leaves	Old leaves	Young leaves	Old leaves	Young leaves	Old leaves	Young leaves	Old leaves
–	–	–	–	–	1:0	+	++	+	++	++	+	+	++
–	–	–	–	–	3:1	–	+	–	+	+	–	–	+
–	–	–	–	–	1:1	–	–	–	–	–	–	–	–
–	+	–	+	+	1:3	–	–	–	–	–	–	–	–
++++	++++	++++	+++++	+++++	0:1	–	–	–	–	–	–	–	–

TABLE 6

Bioefficacy of different *Trichoderma* isolates against different pathogen toxins

Trichoderma isolates	Pathotoxin detoxification seedling dip/detached leaf bioassay against different pathogens*									
	F.solani	*Pythium*	*S.sclerotiorum*	*S.rolfsii*	*R.solani*	*R.bataticola*	*C.capsici*	*A.alternata*	*A.brassisicola*	*P.vexans*
Th 1	+	+	+++	++	+++	+++	+	+	+	++
Th3	-	-	+	-	+	+	-	+	+	++
Th5	++	+	++	+	++	++	++	++	++	++
Th10	-	-	+	-	+	+	-	-	-	-
Th30	-	-	++	+	+	+	-	-	-	-
Th31	-	-	+	+	+	+	-	-	-	-
Th32	-	-	+	+	-	-	-	-	-	-
ThAgr	-	-	+	-	+	+	+	+	+	++
Tv2	++	++	++++	+++	++++	++++	++	++	++	++
Tv4	+	+	+++	++	++	++	+	+	+	++
Tv12	+	+	+++	++	+++	+++	+	+	+	++
Tv15	-	-	++	++	+	+	-	-	-	+

*Th = *Trichoderma harzianum*, Tv = *T.viride*

Where, 0 = healthy , + = a 0.5 cm lesion on the seedling, ++ = more than two lesions on a seedling , +++ = 25-50% stem girdled or damped off, ++++ = more than 50 % blackened area, +++++ = wilted/ dead seedlings

Where 0=healthy,+=1-10%,++=11-12%,+++=26-50%,++++=>50% necrotic area under the drop and +++++=>50% expansion zone around the drop on leaves

TABLE 7

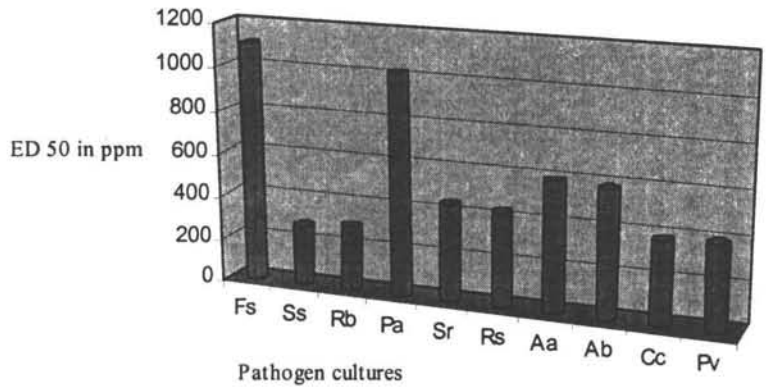
EC_{50} values and, sporulation intensity against and days of complete growth of different isolates against pesticides

Trichoderma spp isolate	Pesticide sensitivity (EC_{50})[a]							
	Benomyl	Captan	Iprodione	Mancozeb	Carbendazim	Thiram ml/ml	Chloropyriphos ml/ml	Pendimithalin
Th 1 (7 days)	2.3	81.6	40	>100	0.1	58.4	1	8
	(0.78)	(3.21)	(4.2)	(8.4)	(0.74)	(7.4)	(0.74)	(4.16)
Th 3 (3 days)	1.2	>100	30	>100	0.2	65.6	2	>10
	(1.15)	(12.8)	(8.16)	(10.7)	(0.86)	(12.9)	(1.00)	(6.19)
Th 5 (7 days)	2..2	>100	40	>100	0.1	65.8	1	8
	(0.89)	(3.45)	(4.1)	(7.9)	(0.55)	(8.4)	(0.81)	(5.21)
Th 10(4 days)	2.2	>100	50	>100	0.2	>100	2	>10
	(0.98)	(4.26)	(7.34)	(10.2)	(0.81)	(10.4)	(0.89)	(6.64)
Th 30(6 days)	2.3	>100	40	>100	0.2	72.4	1	8
	(0.76)	(8.53)	(6.12)	(8.6)	(0.79)	(7.8)	(0.79)	(3.6)
Th31(6 days)	2.8	>100	30	>100	0.1	65.2	1	>10
	(0.78)	(7.46)	(6.21)	(8.9)	(0.82)	(7.6)	(0.74)	(5.6)
Th32(6 days)	2.5	>100	35	>100	0.1	66.4	1	10
	(0.74)	(6.93)	(7.3)	(7.4)	(0.81)	(6.9)	(0.79)	(4.92)
ThAgr(5 days)	2.1	>100	45	>100	0.1	85.8	2	6
	(0.85)	(6.4)	(7.9)	(9.9)	(0.84)	(9.3)	(0.80)	(6.24)
Tv 2(8 days)	1.9	60.5	20	50.2	0.1	48.4	1	10
	(0.74)	(5.86)	(3.1)	(6.3)	(0.66)	(5.3)	(0.78)	(2.26)
Tv 4(8 days)	1.4	65.6	30	58.6	0.1	55.6	1	9
	(0.72)	(10.1)	(4.1)	(7.4)	(0.58)	(3.2)	(0.75)	(6.0)
Tv 12(7 days)	1.6	72.3	40	69.3	0.2	80.2	2	8
	(0.89)	(11.7)	(5.9)	(9.5)	(0.81)	(9.4)	(0.73)	(5.06)
Tv 15(9 days)	1.5	65.8	30	58.2	0.1	55.8	1	8
	(0.46)	(5.86)	(3.5)	(5.3)	(0.53)	(4.2)	(0.72)	(0.53)

[a] Pesticide concentration (µg/ml) which reduces growth by 50% relative to the control.

Days in parenthesis denotes the complete growth of the isolate in petriplate

Figure in parenthesis denotes the sporulation intensity (spores 10^6/ml)



Fs=*Fusarium oxysporum* f.sp. *lycopersici*	Ss= *Sclerotinia sclerotiorum*
Rb= *Rhizoctonia bataticola*	Pa= *Pythium aphenidermatum*
Sr= *Sclerotium rolfsii*	Rs= *Rhizocatonia solani*
Aa= *Alternaria alternata*	Ab= *Alternaria brassisicola*
Cc= *Colletotrichum capsici*	Pv= *Phomopsis vexans*

Figure 2. : Antifungal activity of cultural filtrate extract of *T.harzianum*

TABLE 8

Effect of *Trichoderma harzianum* and *T.viride* on overall performance (%) of tomato under different *Trichoderma* selective isolates

Treatment	Plant vigour* (%)	Root colonization cfu/g soil sample (at x10^6)	Per cent disease control	Per cent over all performance**	Per cent increase over control
1	2	3	4	5	6
***Trichoderma* isolates alone**					
Th-30	74.3 (59.45)	3.1	80.1 (64.23)	52.50	31.38
Th-3	83.5 (66.03)	5.7	85.3 (67.45)	58.16	45.54
Th-5	80.7 (63.94)	4.3	82.1 (64.97)	55.70	39.38
Th-10	82.1 (64.97)	5.2	84.2 (66.58)	57.16	43.04
Th-31	72.1 (58.12)	2.1	76.4 (60.94)	52.20	25.62
Th-Agr	73.4 (58.95)	2.9	78.1 (62.10)	51.46	28.77
Tv-12	76.3 (60.87)	3.4	82.1 (64.97)	53.93	34.95
Tv-15	73.2 (58.76)	2.7	79.2 (62.87)	51.70	29.37
***Trichoderma* isolates + compatible doses of captan (1:1)**					
Th-30	75.2 (60.13)	3.7	80.5 (63.79)	53.13	32.95
Th-3	83.9 (66.34)	6.1	86.3 (68.28)	58.76	47.04

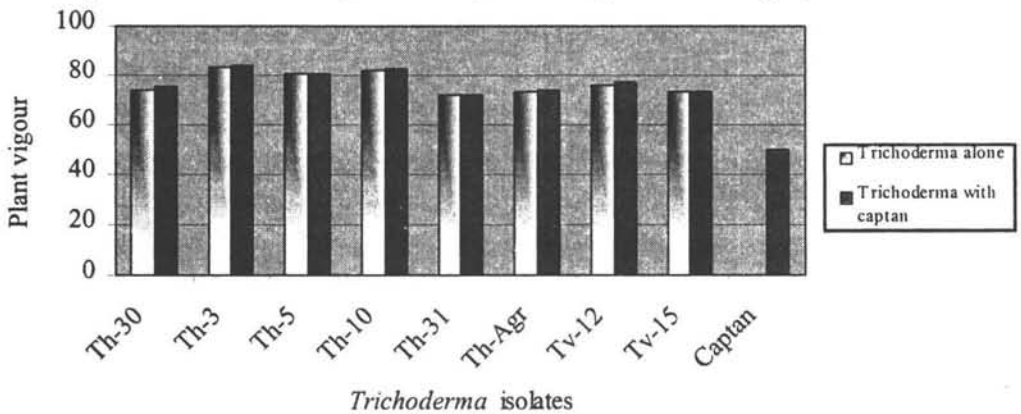
Contd...

...Contd.

1	2	3	4	5	6
Th-5	80.9 (64.08)	5.0	82.9 (65.57)	56.26	40.79
Th-10	82.8 (65.50)	5.9	85.2 (67.37)	57.96	45.04
Th-31	72.2 (58.18)	2.8	77.1 (61.41)	50.70	26.87
Th-Agr	73.7 (59.15)	3.1	78.8 (62.58)	51.86	29.77
Tv-12	77.2 (61.48)	4.0	82.7 (65.42)	54.63	36.71
Tv-15	73.5 (59.02)	3.4	79.9 (63.36)	52.26	30.78
Captan	50.3 (45.17)	1.5	68.1 (55.61)	39.96	–
CD p=0.05	1.0309	0.0847	2.5082		

Figures in parentheses are arc sine transformed values.

* Plant vigour = Germination per cent +(Shoot length +Root length)



* Plant vigour index (%) = Germination per cent +(Shoot length +Root length)

Figure 3 : Effect of *Trichoderma harzianum* and *T.viride* isolates on plant vigour index (%) of tomato challenge inoculation with damping off and wilt.

MODE OF APPLICATION AND SUITABLE DELIVERY SYSTEM

Nursery management has the major role in vegetable production as diseases of seed and seedlings during germination either before or after emergence causes heavy losses. The most common means to check the disease in nurseries is by using fungicides but frequent and indiscriminate use of them often leads to atmospheric pollution and development of resistance in pathogens. Therefore, due to its economic importance a suitable, ecofriendly and economic means is needed to curb these problems in disease management. In this context, biological control is coming up as an alternative strategy for disease management, which is also eco-conscious and eco-friendly (Sharma, 2001 and (2002a) Improved isolate compatible with recommended doses of thiram, captaf, iprodion, and mancozeb showed an increased overall growth/performance of treated tomato, cabbage, cauliflower, chilli and brinjal plants in terms of plant vigor, root colonization and disease control, indicates better performance of *Trichoderma* under solarized soils than

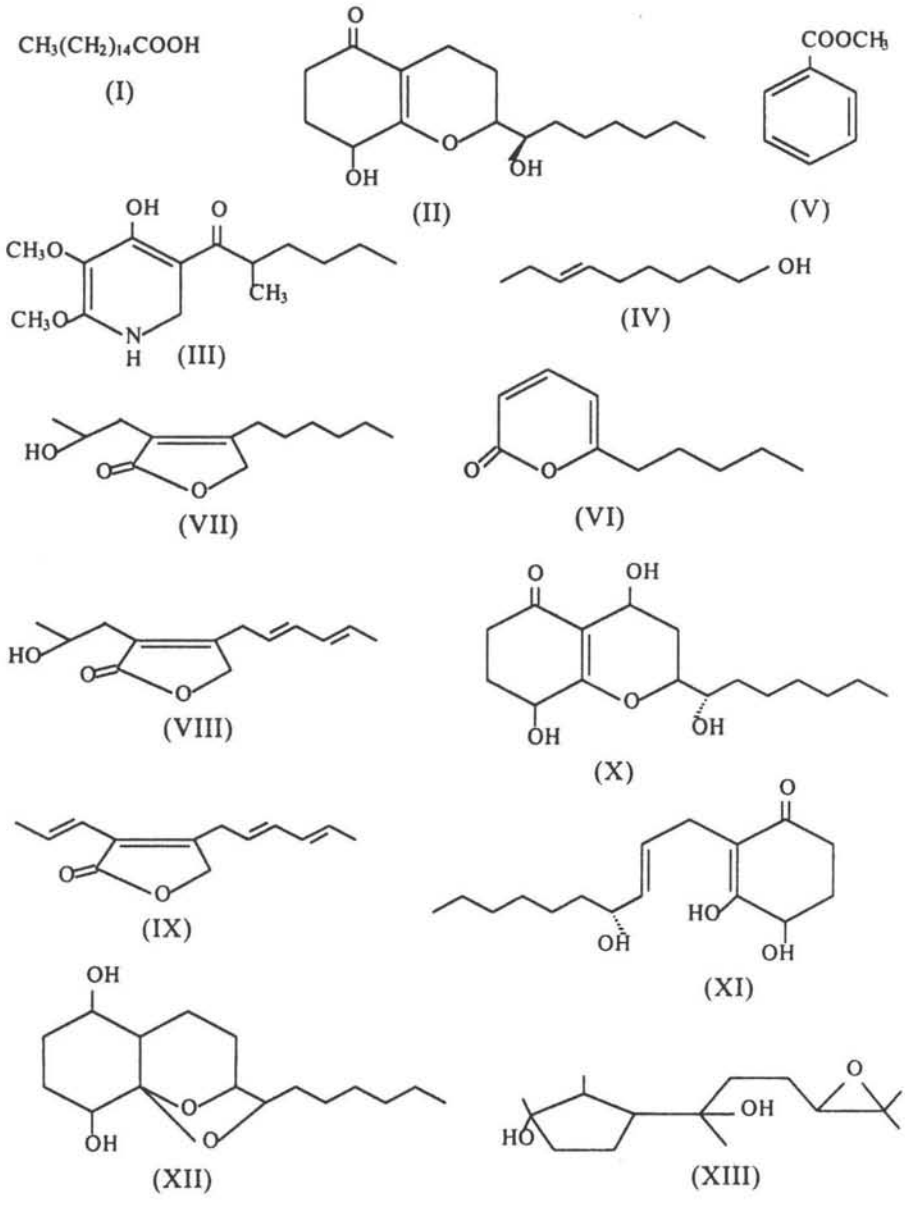


Figure 4 : Secondary metabolites isolated and identified from 28 days old culture filtrate of *Trichoderma harzianum* (Th3)

non solarized soil. Though this isolate was also effective in non-solarized soils using the dose 2g/ kg seed treatment + seedling dip +foliar spray. Rhizosphere observations based on persistence and proliferation of *Trichoderma* isolates in terms of c.f.u./g soil sample were also made (Table 9-14). Studies to test the different nursery IPM module and cropping system to finalize suitable IPM package (nursery modules using varied four components viz., solarization, seed treatment, nursery net and foliar spray of *Trichoderma* and/or iprodione) showed noticeable effective performance when the *Trichoderma* isolate used after solarization, in regular application or as in first two-crop-year under crop rotation system.The best nursery IPM module: solarization of nursery, seed treatment with captaf and *Trichoderma* (1:1), nursery covering with net and foliar spray of *Trichoderma* proved to be the best package. This can be utilized for Integrated Pest Management modules, where pesticides are used with biological methods and therefore, development of pesticide tolerant/ compatible fungal bioagents required.Application of *T. harzianum* in the regular cropping or in the first two year-crop show good results and persist in the rhizosphere , is able to colonize the roots and proliferate 4-5 times on existing and newly formed plant roots and rootlets well after application

The improved isolates *Trichoderma harzianum* Th-3 and Th-10 were compatible with recommended doses of thiram, captaf, iprodione, carbendazim and mancozeb showed an increased plant growth of treated tomato, cauliflower, chilli and brinjal plants and consistently reduced the disease caused by various pathogens. They performed better in plant growth performance under solarization as compared to non-solarized soil however; these isolates also work very well in non-solarized soil. The isolates of *T. harzianum* Th-3 and Th-10 compared for rhizosphere colonization / persistence in soil and effect on plant growth of Th-3 was found better over Th-10 in terms of population persistence, plant growth, and disease control (Fig. 5) (Result on the basis of earlier study in the lab, Sharma, 2002b and Sharma and Sain, 2003). In continuation of this earlier study further experiments were carried out to understand relationship between root colonization/population persistence and plant growth and to develop suitable IPM package for nursery with the use of best isolate.

The *T. harzianum* isolates stimulates plant growth even in the apparent absence of the pathogens because it interact directly with the plant by producing plant growth promoting active metabolites without interacting with pathogens. (Windham *et al.* 1986). Such effects of *Trichoderma harzianum* on plant growth, under solarization and under other experiments were also reported. (Sharma, 2002b and Sharma and Sain, 2003). The performance of *T. harzianum* Th-3 for rhizosphere colonization/persistence in soil and effect on plant growth of solonaceous and cruciferous crops under different cropping system was evaluated to understand the host specificity. Thus, the Th-3 isolate proved to be the best isolate to increase plant growth, disease control and persistence of the spores on the roots/rootlets of tomato crops under crop rotation but are statistically at par. However, the performance of this isolate under mono cropping and crop rotation did not show significant difference in plant growth but it differed significantly in the persistence of its population.

The time of treatment is important for control of disease and plant growth. The studies conducted for evaluation of treatment interval in crop-year did not show significant correlation between treatment interval in cropping year and plant growth. However,

population persistence was found increased with regular treatment and up to some extent in alternate and first two-seasons crop treatment. This shows the spores remain viable in the soil and colonize the roots of crop of further coming season. Thus, the lying of viable spores in the soil/field does not help much in plant growth as compared to the direct use of bioagents on seed, seedlings in the form of seed coating or seedling dip. which indicates that without the host root colonization *Trichoderma harzianum* cannot produce the active metabolites, which are behaving as growth promoting agent.

The different integrated pest management modules including various components viz. seed treatment with Th-3 and captaf (1:1), foliar spray with Th-3 and/or iprodione and other cultural practices like nursery solarization and nursery covering with net proved to be the best IPM package for nursery. This shows that the best control, however, is obtained in an integrated programme using *Trichoderma* spp. with reducing doses of fungicide (Gullino, 1992; Harman *et al.*, 1996; Tronsmo, 1989; Papavizas and Lewis 1983 and Papavizas *et al.*, 1982). Seed treatment and seedling dip with *Trichoderma harzianum* isolate proved to be the best-option along with *T. harzianum* Th-3 and captaf, where the studies showed captaf to be the safest fungicide for *Trichoderma*. The chemical protectant can provide the short-term protection of the seed or seedling itself. A rhizosphere-competent and pesticide tolerant/ resistant bioprotectent, on the other hand can colonize the entire root system and provide degree of season-long protection unattainable through acceptable levels of only chemical treatment. (AbdEl Moiety *et al.*, 1982, and Tronsmo 1986, 1991)

By replacing some of the chemical treatments, the biological agent reduces both environmental pollution and the danger of the pathogen developing fungicide resistance. The regular applications of the biocontrol agent, which can establish itself in the infection court, thus, provide localization, persistence and plant growth unattainable by chemicals itself/or alone. Therefore, and due to its broad spectrum effect through a variety of mechanisms areas in which biological agent are superior to chemical components, further research should be directed toward exploiting such niches.

TABLE 9

Effect of cropping system and method of application on persistence of *T. harzianum* population in rhizosphere of solonaceous crops (in terms of cfu/g soil)

Crop treatments	Overall persistence in terms of cfu/g soil (at10^6 Dilution)* application method v/s cropping system								
	Mono cropping			Crop rotation-I			Crop rotation -II		
Regular crop treatments	Tomato	Tomato	Tomato	Tomato	Chilli	Tomato	Tomato	Brinjal	Chilli
Seed	3.5	4.0	5.0	3.5	4.5	5.5	3.5	4.5	5.0
Seedling dip	4.5	5.0	5.5	4.5	5.5	6.0	4.5	5.5	6.0
Seed+ seedling dip	5.0	5.5	6.0	5.0	6.0	6.5	5.0	6.0	6.5

*Average means of three replication are significantly different at DMRT $P_{0.05}$ =1.321

TABLE 10

Effect of *T.harzianum* on over all growth performance of solonaceous crops under different cropping system and method of application

Crop treatments	Overall plant growth performance (application method v/s cropping system)*								
	Mono cropping			Crop rotation-I			Crop rotation -II		
Regular crop treatments	Tomato	Tomato	Tomato	Tomato	Chilli	Tomato	Tomato	Brinjal	Chilli
Seed	72.23	73.12	72.14	72.13	73.24	72.42	72.24	72.13	73.13
Seedling dip	74.16.	74.46	74.56	74.20	74.84	75.12	74.18	74.28	74.32
Seed+ seedling dip	79.52	80.12	80.15	79.54	80.13	80.74	79.61	79.42	80.82

*Average means of three replication are significantly different at DMRT $P_{0.05}$ =2.00789

TABLE 11

Effect of cropping system and method of application on persistence of *T. harzianum* population in rhizosphere of cruciferous crops (in terms of cfu/g soil)

Crop treatments	Overall persistence in terms of cfu/g soil (at10^6 Dilution)* application method v/s cropping system								
	Mono cropping			Crop rotation-I			Crop rotation -II		
Regular crop treatments	Cauliflower	Cauliflower	Cauliflower	Cauliflower	Cabbage	Cauliflower	Cauliflower	Cabbage	Broccoli
Seed	3.4	4.1	5.1	3.5	4.5	5.6	3.4	4.5	5.2
Seedling dip	4.5	5.0	5.4	4.4	5.4	6.1	4.6	5.5	6.0
Seed+ seedling dip	5..1	5.6	6.1	5.1	6.0	6.6	5.1	6.1	6.5

*Average means of three replication are significantly different at DMRT $P_{0.05}$ =1.216

TABLE 12

Effect of *T. harzianum* on over all growth performance of cruciferous crops under different cropping system and method of application

Crop treatments	Overall plant growth performance (application method v/s cropping system)*								
	Mono cropping			Crop rotation-I			Crop rotation -II		
Regular crop treatments	Cauliflower	Cauliflower	Cauliflower	Cauliflower	Cabbage	Cauliflower	Cauliflower	Cabbage	Broccoli
Seed	71.21	73.42	74.14	72.43	73.04	72.42	72.01	72.09	73.45
Seedling dip	73.76.	74.66	74.86	74.50	74.68	75.12	74.48	74.43	74.36
Seed+ seedling dip	79.53	80.32	80.55	79.84	80.48	81.23	80.12	79.88	80.89

*Average means of three replication are significantly different at DMRT $P_{0.05}$ =2.495

TABLE 13

Population persistence of best *Trichoderma harzianum* isolate in the rhizosphere under different treatment interval in cropping system(tomato)

Treatment method	Overall persistence in terms of cfu/g soil (at10^6 Dilution)**											
	I st *			II nd *			II rd *			IV th *		
	A Th	B –	C Th	A Th	B –	C –	A Th	B Th	C –	A Th	B Th	C Th
Seed	3.5	2.5	4.5	3.5	2.5	3.5	3.5	4.0	4.5	3.5	4.0	5.0
Seedling dip	4.5	2.5	5.0	4.5	2.5	3.5	4.5	5.0	5.0	4.5	5.0	5.5
Seed+ Seedling dip	5.0	3.5	5.5	5.0	3.5	4.5	5.0	5.5	5.5	5.0	5.5	6.0

* Application of *Trichoderma* at different crop-year system.

A=I season, B=II season, and C= III season

**Average means of three replication are significantly different at DMRT $P_{0.05}$ =1.328

Use of *Trichoderma* in India

Trichoderma is a wonder microbial bioagent being used and researched by almost all workers. In India it has been widely applied and bioagents have also been used (Table 15, 16 and 17) against different diseases. Since, today IPM and Organic Farming have become important components of crop protection, the demand of biological formulations is increasing as reflected in Table 17. They are being ultilized in almost all agricultural

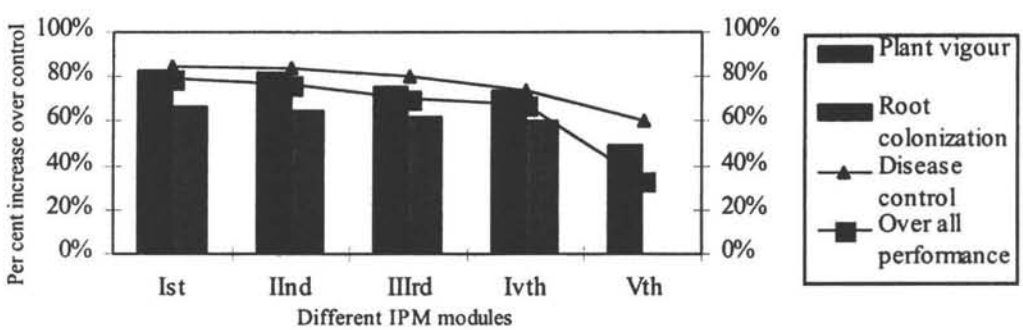
crops. Vegetables occupy highest position (Fig. 6). List of different bioagents used against diseases of vegetable crops is compiled in (Table 18) signifying importance of use of bioagents.

TABLE 14

Effect of *T. harzianum* on over all performance under different treatment interval in cropping system (tomato)

	Overall plant growth performance**											
Treatment	Ist *			IInd *			IIrd *			IVth *		
method	A	B	C	A	B	C	A	B	C	A	B	C
	Th	–	Th	Th	–	–	Th	Th	–	Th	Th	Th
Seed	72.13	15.12	72.03	72.29	14.92	22.18	73.14	72.34	16.32	73.40	73.25	73.59
Seedling dip	74.13	15.29	72.24	74.34	15.13	23.75	75.32	75.16	16.45	74.75	75.32	75.85
Seed+ Seedling dip	79.75	15.32	79.21	80.12	15.46	28.82	79.80	79.35	16.13	79.73	80.45	80.75

* Application of *Trichoderma* at different crop-year system.



*Each bar is average means of three replication are significantly different at DMRT $P_{0.05}$ =2.6945

Fig. 5 : Effect of *Trichoderma harzianum* on overall performance (%) of tomato under different nursery IPM modules

A=I season, B=II season, and C= III season

**Average means of three replication are significantly different at DMRT $P_{0.05}$ =2.624

TABLE 15

Indian research on *Trichoderma* (30 Years)

Area	No. of Publications	
	World	India
Biocontrol potential	841	237 Molecular
Biology & ISR	399	42 Formulation
141 56		
Shelf Life 23	12	
Delivery & Evaluation	1351	569
Species Registered	11	2
Product Available	257	23

Area of work	*T.harz*	*T.viride*	*T.virens*	*P.fluo*	Total
Genetic Improvement	2	1	0	2	5
Cost-effective mass Production	15	7	4	10	36
Formulation Development	8	7	2	3	20
Formulation evaluation	80	46	10	80	216
Enhancing shelf life	5	4	2	5	16
Application delivery and equipment	10	4	1	5	20

TABLE 16

Other potential antagonists

Sporedesmium sclerotivorum	Sclorotium forming fungi
Coniothyrium minitans	Sclorotium forming fungi
Pythium oligandrum	Damping off
Ampelomyces quisqualis	Powdery mildew pathogen
Talaromyces flavus	Sclerotinia, Verticilium dahliae
Bacillus subtilis	Soil borne Pathogen
Debareyomyces hansenii	Post Harvest Pathogen
Candida olephila	Post Harvest Pathogen
Saccharomyces cerevisiae	Post Harvest Pathogen
Rhodosporidum toruloides	Post Harvest Pathogen

TABLE 17

Requirement of bio-control agents in India

Bioagent	Country need	Value Rs. in Crores	Prod. Capacity	Qty. Prod. (2004)	Sold (2004)
Trichoderma (T)	22038	260.78	1850(8.4)	382(20.6)	326(85)
Pseudomonas (T)	11421	228.42	705(6.2)	205(29.0)	170(83)
Trichogramma (L)	176305	652.33	832(0.5)	404(48.6)	317(78)
Crysoperla (Lakhs)	459420	9.42	26(<0.1)	9(34.6)	8(89)
Cryptolemus	106	1.06	25(24.0)	16() 64.0	11(89)
(Lakhs)	2551	714.28	17(), 0.7	7() 41.2	5(71)
HaNPV (Kiloliters)	1971	542.03	6(0.3)	10(16.6)	1(100)
SINPV (Kiloliters)	341	-	–	–	–
C_1GV (Kiloliters)	1341	0.0188	436(32.5)	29(6.7)	15(51)
Verticillium (T)	6117	0.098	755(12.3)	214(28.3)	195(91)
P. lilacinus (T)	525	0.01	39575.2	31(7.8)	21(67)
M.Anisoptiac (T)	3671	48.36	2(0.02)	0.58(29)	0.39(67)
Gonlozus (Lakhs)	9671	-	–	–	–
Normurea (T)	9082	–	–	–	–
AaNPV (KL)	505	–	–	–	–
PxGV (KL)	18	–	–	–	–

Source : Lecture by Dr.R. J. Rabindra, Director PDBC, Bangalore in Brainstorming on Integrated Pest Management and Biopesticides (26 April, 2006).

SUCCESSFUL APPLICATION OF TRICHODERMA SPECIES IN ECONOMICALLY IMPORTANT AGRICULTURAL CROPS IN INDIA

CEREALS : Rice, Wheat, Sorghum, Bajara, Maize, Pearlmillet, Barley

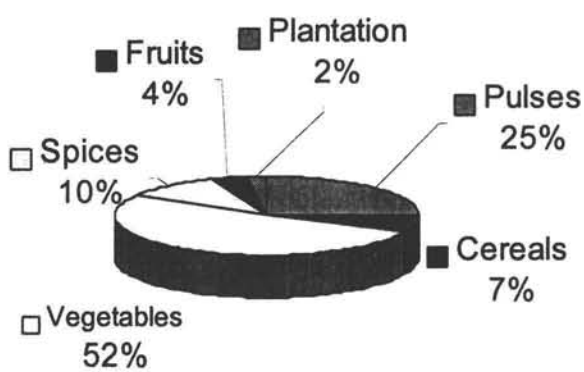


Figure 6 : Use of bioagents in different crops

PULSES : Chickpea, Pigeonpea, Mothbean, Mungbean, Urdbean, Cowpea, Horsegram, Guar, Lentil, Fingermillets, Soybean,Linseed

OILSEED CROPS : Sesamum,Mustard, Sunflower, Groundnut, Safflower, Coconut

FRUITS & VEGETABLES : Papaya, Guava, Citrus, Apple, Banana, Mulberry Muskmelon, Tomato, Potato, Pea, Wingedbean, Chilli, Okra, Ginger, Onion, Cauliflower, Cabbage, Frenchbean, Cucurbits, Elephant Foot Yam, Brinjal, Betelvine, Watermelon, Patchouli

ORNAMENTALS : Gerbera, Carnation, Gladiolus, Jasmine, Chrysanthemum, Balsam, Rose

SPICES : Black Pepper, Cumin, Coriander, Cardamon, Fenugreek

OTHERS : Cotton, Sugarcane, Sugar beet, Tea, Coffee, Tobacco, Hevea, Cassava, Tamarindus, Jojoba, Jute, Tropical Pines, Dalbergia, Neem, Acasia, Flax, Cymbopogons, Teak, Eucalyptus, Cocoa, Aubergine, Chairpine, *Prosopis juliflora*

TABLE 18

Use of antagonists against diseases of vegetable crops

Crop	Pathogens	Antogonists	Reference
1	2	3	4
Beans	*B. cinerea*	*Psundomonas arruginota 7NSK2* *T. harzianum T39*	Have *et al.*, 1999
	White mold *Sclerotinia sclerotionum*	*Bacillus subtilis* *A.alternata Cladospopium cladoxporioides Drechslera sp.* *Epicocum nigrum* *Myrothecium verrucaria* *Penicillicum sp. T.viride*	Boland 1997
Brinjal	Damping off *Pythium*	*T. harzianum* *Lactisaria asvatis*	Jacob *et al.*, 1988
	aphanidermatum Sclerotium rolfsii, sacc	*Trichoderma spp*	Cuevas 1998
	Pre-emergence Damping off *Pythium aphanidermatum*	*T. harzianum* *Laetisaria arvalis*	Jacob *et al.*, 1988 Kewus & Larkin 1997
	Damping off *R. solani* *P. ultimum*	*C. foecundissimum*	Lewis & Larkin 1999
	Damping off	*Actinomycetes*	Bucki *et al.*, 1998

Contd...

...Contd.

1	2	3	4
	Fusarium spp *Pythium spp* *Rhizoctonia spp*	*Fluorescent* *Pseudomonads* *Trichoderma sp.*	
	Verticullium wilt *Vertrcillium dahliae*	*Gliocladium spp*	Watanabe 1994
Cucumber	*Pythium aphanidermatum (Edson) Fitz.*	*Penicillium* *Pinophinum* *T. harzianum P. capitatum*	Sharif *et al.*, 1988
	Rhizosphere competence	*T. harzianum*	Ahmad & Baker 1987
	S. sclerotiorum *B.cinerea* *Sphaecotheca Fuliginea* *Didymrella bryoniae*	Trichoderma T7	
	Stem infection Botrytis cinerea	*T. harzianum T-39* *Aureobasidium kpullulans* *Cryptococuss albidus*	Dik and Elad 1999
Cauliflower	*Sclerotinia* stalk rot	*T. viride A. terreus* *Rhizopus arrhizus*	Gupta & Agarwala 1998
		Fusarium solani *T. harzianum*	Sharma and Sain 2003
Chilli	Damping off *Pythium aphanidermatum*	*T. viride Pseudomonas fluorescens*	Manoranjitham and Prakasam 1999, 2000 Manoranjitham *et al* 2000a, 2000b
	Pythium aphanidermatum *Meloidogyne incognita* disease complex	*T. viride T. harzianum* *Paecilomyces lilacinus*	Karthikeyan *et al, 1999*
	Damping off *P. aphanidermatum*	*T. viride* *Psendononas fluocrescons*	Manoranjitham *et al* 2000
	Fruit rot & Die back *Colletotrichum capsici*	*T.harzianum*	Sharma *et al.* 2005

Contd...

...Contd.

1	2	3	4
Carrot	Storage rot *Botrytis cinerea* *Mycocentrospora acerina* *Rhizoctonia carotae* *Sclerotium sclerotiorum (Sclerotinia)*	*T. harzianum*	Tronsmo 1989
Onion	White rot *Sclerotium cepivorum*	*Trichoderma spp. C62 UV3* *Chaetomium globosum*	Kay & Stewart 1994
Potato	*Verticillium dahliae*	*T. harzianum*	Ordentilich *et al.*, 1990
	Potato pink rot *Phytophthora erythroseptica*	*T. harzianum* *T. konigii T. viride*	Ordentilich *et al.*, 1994
Pea	Powdery mildew *Erysiphe polygoni*	*Trichoderma viride*	Rajappen & Yesuraja, 2000
	Root rot disease *S.rolfsii* *Rhizoctonia solani* *Fusarium solani*	*T. harzianum T. viride*	Abo *et al.*, 1998
	White mold *Sclerotinia sclerotiorum*	*Penicillium cyclopium* *Paecilomyces lilacinus* *A. niger* fumigatus *Acremonium implicatum* *Trichothecium roseum* *Trichoderma harzianum*	Singh 1991
	Rhizosphere Competance	*T. harzianum*	Ahmad & Baker, 1987
Radish	*Peronospora brassicae*	*T. harzianum*	Bedlan 1997
Sesame	*Macrophomina phascolina*	*T. viride*	Gupta & Cheema 1990
Snap bean	*Sclerotina sclerotiorum*	*T. viride*	Delgado & Arbelaez 1990
	Root rot *R. solani*	*T. harzianum* *T. koningii*	Liu, 1991

Contd...

...Contd.

1	2	3	4
Tomato	*Botrytis cinerea*	T harzianum	Jalil and Carlos 1997
	Sclerotium rolfsii	T. viride	
	Damping off *P. aphanidermatum*	T. viride *Pseudomonas fluorescens*	Manoranjitham & Praksam, 1999
	Rhizosphere competence	*T. harzianum*	Ahmad & Baker, 1987
	Root knot wilt *Meloidogyne javanica* *Fusarium oxysporum f.sp. lycopersici*	*Paecilamyces Lilacinus* *Trichoderma spp.*	Stephan *et al.* 1996.
	Early blight *A. solani*	*T. viride*	
	Fusarium wilt *F. oxysporum f. sp lycopersici*	*Gliocladium Virens* *Gliocladium Catenulatum*	Watanabe 1994
	Fusarium wilt *F. oxysporum f.sp. lycopersici*	*Serratia plymithica* *Psendomonas spp*	Frommel *et al* 1991
	Phytophthora infestans	*Serratia sp Trichoderma sp* *Fusarium sp Penicillium spp*	Garita *et al* 1999
	Root rotting *Fusarium sp* *Alternaria sp* *Botrytis sp* *Pythium sp*	*T. harzianum Rifai Aggr.*	Gromovikh *et al,* 1998
	Soil borne disease *Rhizoctonia solani* *Pythium ultimum* Or in combination with *Sclerotium rolfsii* & *Fusarium oxysporum f.sp.lycopersici*	*Gliocladium virens (Gl-3)* *Burkholderia cepacia (Bc-F)* *or Gl-3+Bc-F*	Krishnamoorthy and Bhaskaran 1990
	Wilt *Fusarium oxysporum f. sp.lycopersici*	*Penicillium purpurogenum*	Larenas and Montedegre 1996

Contd...

...Contd.

1	2	3	4
	Root rot *Sclerotium rolfsii Rhizoctonia solani Fusarium solani*	*T. harzianum T. viride*	Abo *et al* 1998
	Grey mould *Botrytis cinerea*	*T. harzianum & Verticillium lecanii*	Yohalem *et al* 1998
	Fusarium wilt *Fusarium oxysporum f.sp. radicis-lycopersici* spores	*Pseudomonas putida (AP-1)*	
Various crops	*Sclerotium rolfscii R. solani Pythium spp. Fusarium spp.*	*T. harzianum*	Ordenthch & Chet, 1989 Cuevas *et al* 1996

One of the most difficult steps in the commercialization of a BCAis to produce, package and deliver sufficient quantities of a bioagent in a stable and viable form. Different types of carriers, agriculture substrates, shelf life are the major features for the production and formulation

Importance of registration of biofungicide

- It is important that better quality biofungicide product be registered according to the norms set by Central Insecticide Board.
- To produce biofungicide in laboratory is one thing and its large scale production after registration from CIB is another thing. It requires certain specified parameters.
- Biofungicide is registered under CIB Act under section 9 (3B) and 9 (3)

Basic Information required on the product for registration

- Strain specifications
- CFU count
- Target fungi
- Moisture Content
- Type of formulation
- Technical bulletin/Product profile

Strain Specifications

- Genus & Species: *Trichoderma harzianum*
- Rhizosphere competence
- Biological control capability
- Growth promotion capability
- Wide range of growth parameters like pH and temperature

CFU count & Shelf life

- The data required for claiming one year shelf life of the product is for 15 months for talc based formulation i.e. the microbe should remain viable for 15 months with a cfu count not less than 2 x 106 spores/ml or g on selective media (TSM).
- The pathogenic contaminants such as *Salmonella, Shigella and Vibrio* should not be present. Other microbial contaminants not to exceed 1 x 10^4 counts per ml or g.

Moisture Content

- Maximum moisture content of the product should not exceed more than 8 per cent.

Chemistry

- Systematic name: Genus and species
- Common name, if any
- Natural occurrence—morphological description
- Manufacturing process—solid or liquid state fermentation
- Qualitative analysis
- CFU on selective medium
- Absence of Gram -ve bacterial contaminants (*Salmonella, Shigella and Vibrio*)
- Moisture content
- Shelf life claim—two different location along with meteorological data

Bioefficacy

- Laboratory test: The product should be tested at one of the laboratories of ICAR/ SFU/CSIR/ICMR system
- Field test: the result of field trials conducted under Indian conditions
- Data on non-target organisms

Toxicity

Toxicological studies may be conducted by recognized institutes viz., ITRC, Lucknow, INTOX, Pune, IIBAT, Chennai etc.

(a) (For formulated products to be directly manufactured)

Single dose oral—Rat (21 days) (Toxicity/Infectivity/Pathogenicity)

Single dose oral—Mouse (21 days) (Toxicity/Infectivity/Pathogenicity)

Single dose Pulmonary—Rat (14 days) (Toxicity/Infectivity/Pathogenicity)

Single dose Dermal—Rabbit (21 days) (Toxicity/Infectivity/Pathogenicity)

Single dose Dermal—Intraperitoneal (21 days) (Toxicity/Infectivity/Pathogenicity)

Primary skin irritation

Eye irritation

Human Safety Records

Environmental Toxicological Studies

(For formulation only)

Non Target Vertebrates Toxicity to Chicken

Toxicity to Pigeon

Toxicity to Freshwater Fish Toxicity to Chicken

Toxicity to Pigeon

Toxicity to Freshwater Fish

Dossier Preparation for 9(3b) & 9(3) registration

Follow Up

Packaging and labeling

- Packaging

1. Classification—solid, liquid or other type of product
2. Unit pack size—in metric system
3. Specification—details of primary, secondary and transport packs

- Labels and leaflets

As per Insecticides Act, 1971 Common name, composition, antidote/storage statements etc. (The packaging material should also be ensured free from contamination during handling, storage and transportation).

Obstacles in commercialization

The causes for failure or inconsistent perfomance of the formulations developed are

- the low disease pressure for the test to be effective,
- the treatment favouring the increased damage from the non-target diseases,
- the variable root colonization by the introduced strain or the loss of ecological competence by the strain and
- the production of antibiotics, wherever it is necessary, is either too late or too low in quantity that it does not prove to be effective for controlling the disease.
- The obstacles mentioned earlier drive away the researchers or the funding is short-term to work out these problems for the development of effective development of the commercially viable products.
- The other problems are related to the institutes, technical limitations and unrealistic expectations.
- These must be overcome if we are to give any thought to the development of commercial products for plant disease management.

Economics

- Economics is the key and a major barrier to the development the of the biocontrol fungi for the use in disease management.
- Primarily, a limited market pays the developmental and registration costs and mostly it is disease specific for a single crop. In most of the cases, either there is no established infrastructure for scale up and commercialization of biocontrol agents.
- Otherwise the market is infant, which does not prove economically viable and there is no impetus for the development of such products.

- Significant changes in the infrastructure facilities need to be done for the use of biocontrol agents to be effective against one disease on one crop as has been achieved on sweet corn in USA.

Selection of suitable strains

The strains should possess following properties

- Biocontrol ability and/or growth promotion
- Rhizosphere competent
- Wider growth parameters like pH, temperature
- Broad spectrum

Mass production of fungal antagonists on suitable agri and industrial wastes

Mass production should be done on wastes which are not used for human/cattle consumption

- Substrates should be
  1. economically viable
  2. easily available

DEVELOPMENT OF BIOFORMULATION

The bioformulation of antagonists with optimum biocontrol potentiality should possess several desirable characteristics such as ease for preparation and application, stability, adequate shelf life and low cost (Lisansky, 1985). The biomass produced is separated by filtration or centrifugation, then be dried and milled prior to its incorporation into dusts, granules, pellets, wettable form or emulsified liquid. The drying process may influence the viability of propagules in biomass. The *Trichoderma* propagules survived differently in three drying processes i.e. pan drying, spray drying and lypophilized. Viability was maximum in pan drying and was least in lyophilized process (Lumsedan and Lewis, 1989). A number of *bioformulations* are marketed in developed and developing countries for the management of plant diseases (Table 2). Even in Indian market now days, several *Trichoderma and bacteria* based bioformulations are available (Table 3 & 4). At present, total production of biofungicides in India is 1-2% of the total pesticide production. Availability of *Trichoderma* based bio-pesticides in India is over 500 tonnes and main constraints are quality and stability. It is estimated to increase up to 15-20 per cent within a decade or so (Saksena, 2000).

The talc based formulation of *T. viride* such as Biogaurd, Ecoderma, Funginil, Biocure-F are marketed by private companies for the control of primarily soil - borne diseases of wide variety of agricultural, horticultural, and agro-forestry crops. Certain educational institutes such as Agricultural Universities of states or ICAR Research Stations have developed their own formulations and recommended for the use of farmers. A talc based formulation of *T. viride* prepared by Tamil Nadu Agricultural University. Coimbatore has been widely accepted by the farmers of Tamil Nadu state for the biocontrol of seedling blight, root rot and wilts of mungbean, urdbean, groundnut, seasamum, sunflower etc. (Vidyasekaran *el al.*, 1995). Similarly Punjab Agricultural University, Ludhiana has developed wet and dry formulation of *T viride.* The potato seed tubers treatment in 2 per cent wet formulation of *T viride* along with 2 per cent molasses for 10 minutes has been recommended for the control of black scurf of potato by the PAU. The mixtures of wheat straw and wheat bran or tea leaves with 3.5 per cent molasses were sterilized

in the poythene bags, inoculated with spore suspension of *Trichoderma* and incubated for 8 days. Well grown culture was used as wet preparation. Similarly, 3 dry powder formulations, based on talc, charcoal powder or ash were developed. The formulation based on charcoal powder gave maximum, more than 3 months shelf life of antagonists at both room and low temperature storage (Singh and Kaur, 2001). A chlamydospores preparation of T *harzianum* and G. *virens* with more than 7 months shelf life was found effective against R. *solani, Fusarium spp., Sclerotium rolfsii* and *Pythium* spp. (Mishra *et al.,* 2001). Another *Trichoderma* chlamydospore formulation "Trichogaurd" has been developed by Arm Biotech International, Faridabad with a claim of more than 9 months shelf life. Even after 270 days of storage, the population of bioagent was found higher than the required 2 x 10^6 CFU/g (Jagtap, 2001).

Five formulations of *A.niger* namely Kalisena-LS, Pusa Marida and Kala Sipahi (for soil application) and Kalisena -SD as well as Beej bandhu (seed dresser) formulation have been developed by IARI, New Delhi. First four formulations have an extra ordinary shelf life of more than two years at room temperature (15-35°C) when packed in polythene bags and stored under less than 80 per cent relative humidity (Sen *et al* 2000).

Talc based formulation of *Pseudomonas fluorescens* preparation has also been developed by TNAU, Coimbatore for the biocontrol of several soil borne plant pathogens. The application of P. , *fluorescens* was also effective in suppression of rice diseases (Vidhyasekaran *et al.,* 1997). A private company T-Stanes and Co., Coimbatore is also marketing talcbased formulation of *P. fluorescens* by trade name Biocure-B for the management of bacterial and soil borne diseases.

A study was made to develop a mass production medium for the *Trichoderma harzianum* using indigenous agricultural products and byproducts under the NATP CGP/ 399 entitled " Development of bioformulation from the improved strains of *Trichoderma* spp. for cauliflower and tomato" (Sharma 2003).

TABLE 19

Some important substrates used all over the world for mass production of biocontrol agents

Powdered rye grass seeds	Talc formulation
Diatomaceous earth granules + molasses	Coffee fruit skin and cherry husk
Wheat bran formulation	Alginate-Wheat bran
Wheat bran saw dust formulation	Coconut coir pith
Rice bran	Alginate pellets
Wheat bran peat formulation	Vermiculite wheat bran and cellulose granule formulation
Sorghum, bajra, ragi and maize seeds	Distilled waste of aromatic plants
Sugarcane and Maize straw and maize cob powder	Soy flour and molasses
Tapioca rind or thippi substrate	Sandal wood distillation waste
Molasses - yeast medium	Tea leaf waste
Banana pseudostem	Compost
Distilled waste of aromatic plants	

TABLE 20

Effect of solid and semi-solid agricultural product and byproducts on mass multiplication of *Trichoderma harzianum*

Substrate	Total biomass (g kg^{-1} dry substrate)	Spore production (spore g^{-1} dry substrate)	Per cent viable spores
Cluster bean grains	375.1	4.6×10^7	90.8 (72.34)
Sorghum grains	450.9	7.2×10^9	95.4 (71.61)
Rice grains	195.1	2.9×10^3	85.2 (67.37)
Wheat grains	257.2	4.5×10^5	88.2 (69.91)
Pearl millet grains	392.5	6.1×10^9	93.7 (75.46)
Rice bran	223.4	3.1×10^5	86.2 (68.19)
Wheat bran	280.6	4.9×10^8	89.9 (71.47)
Neem cake	353.7	4.8×10^8	87.5 (69.31)
Ground nut cake	392.0	6.2×10^8	90.6 (72.15)
Sesamum cake	375.2	5.5×10^8	89.2 (70.81)
Cotton seed cake	275.6	2.1×10^8	84.3 (66.66)
Mustard cake	362.1	4.9×10^8	87.8 (68.70)
Coconut cake	361.8	3.7×10^8	84.2 (66.58)
Mushroom byproducts	426.1	6.8×10^9	94.3 (76.19)
Sugarcane molasses	341.5	4.2×10^9	90.1 (71.66)
Sugar cane baggase	205.4	2.3×10^6	87.3 (69.12)
Eragostis tenella straw	326.1	6.5×10^8	90.8 (72.24)
CD (p=0.05)	22.099		5.440

*The data in parenthesis are arsine transformed prior to analysis.

Among the semi-solid and liquid substrates media evaluated for mass production of *Trichoderma harzianum*. sorghum grain and *Agaricus bisporus* mushroom extract (20%) was found to be the best. These media supplemented with K_2HPO_4, mancozeb and sucrose showed increased biomass production, spore concentration and spore viability (Sharma 2004c). The total biomass production remained increased up to 40 days of incubation, however the maximum spore concentration (6.7×10^{10} and 7.2×10^{10} g^{-1}) and spore viability (98.2 and 98.9 %) was observed after 25 and 20 days of incubation in both the lab formulation, respectively at 25 ±2°C (Table 20-23). The spores of *T.harzianum* remain viable up to 12 months at 5°, 20° and 30±5°C storage in both the bioformulations, although at 5° C the spore viability remain higher (62.1-65.8%) as compared to 20° and 30±5°C after 12 month storage. A seed treatment dose of *T.harzianum* @ 2-4 g kg^{-1} seeds could be recommended for cauliflower and tomato seed treatment, which eventually resulted in, improved seed germination, plant vigour index and provide protection against soil borne diseases. (Sharma 2003)

TABLE 21
Effect of liquid agricultural product and byproducts on mass multiplication of *Trichoderma harzianum*

Substrate	Total biomass (g kg^{-1} dry substrate)	Spore production (spore g^{-1} dry substrate)	Per cent viable spores
Potato dextrose broth	8.01	6.7×10^9	88.3 (70.00)
Trichoderma specific media Proth	8.08	6.9×10^9	88.9 (70.54)
Oat meal broth	7.52	4.5×10^9	87.3 (69.04)
Coconut water	8.25	7.3×10^9	92.3 (73.89)
Mushroom extract 5%	9.12	2.1×10^{10}	93.2 (74.88)
Mushroom extract 10%	9.16	4.2×10^{10}	94.8 (76.82)
Mushroom extract 20%	9.22	5.6×10^{10}	95.2 (77.34)
Molasses broth 2%	8.29	1.8×10^{10}	91.5 (73.05)
Molasses broth 4%	8.32	3.4×10^{10}	92.8 (74.55)
Molasses broth 6%	9.04	5.3×10^{10}	93.7 (75.46)
CD (p=0.05)	1.664		2.593

*The data in parenthesis are arsine transformed prior to analysis.

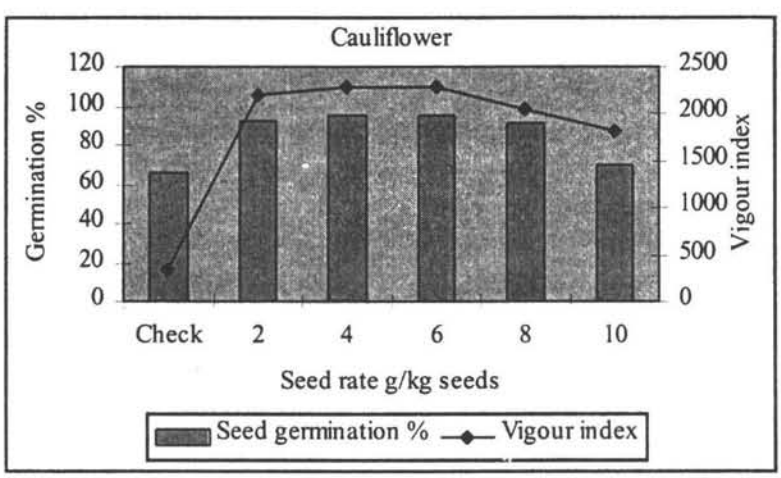


Figure 7a : Effect of doses of bioformulation on seed germination and plant vigour index of cauliflower

TABLE 22

Effect of chemical supplements on semi-solid (sorghum grain) and liquid (mushroom extract) substrate on mass multiplication of *Trichoderma harzianum*

Suppliments g L^{-1} medium	Sorghum grains			Mushroom extracts (20%)		
	Total biomass (g kg^{-1} dry substrate)	Spore production (spores g^{-1} dry substrate)	Per cent viable spores	Total biomass (g L^{-1} dry substrate)	Spore production (spore g^{-1} dry substrate)	Per cent viable spores
$CaCo_3$ 4g	445.6	6.8×10^9	89.5 (71.09)	8.15	7.1×10^9	89.9 (71.47)
Sucrose 0.2g	469.8	8.6×10^9	96.2 (78.96)	9.59	8.9×10^9	96.8 (79.69)
K_2HPO_4 0.18g	455.9	8.2×10^9	96.7 (79.53)	9.28	8.8×10^9	97.2 (80.37)
Mancozeb 0.2g	471.2	1.2×10^{10}	96.9 (79.85)	9.82	2.5×10^{10}	97.5 (80.90)
$CaCo_3$ + sucrose	457.8	8.1×10^9	91.6 (73.15)	9.28	8.4×10^9	92.3 (73.78)
$CaCO_3$ + K_2HPO_4	450.3	7.9×10^9	90.2 (71.76)	9.24	8.1×10^9	90.9 (72.44)
$CaCO_3$ +mancozeb	461.2	8.5×10^9	91.3 (72.84)	9.41	8.5×10^9	92.4 (74.00)
Sucrose +mancozeb	510.7	4.2×10^{10}	97.1 (80.19)	10.41	4.8×10^{10}	98.2 (82.29)
Sucrose+K_2HPO_4	488.4	3.8×10^{10}	97.2 (80.37)	10.25	4.1×10^{10}	98.3 (82.51)
K_2HPO_4+mancozeb	484.3	9.1×10^9	97.8 (81.47)	10.160	9.5×10^9	98.5 (82.73)
$CaCO_3$+sucrose+K_2HPO_4	482.9	3.1×10^{10}	94.2 (76.06)	10.02	3.5×10^{10}	95.2 (77.34)
K_2HPO_4+sucrose+mancozeb	526.8	5.8×10^{10}	98.2 (82.29)	10.52	6.2×10^{10}	98.9 (83.93)
Control	450.9	7.2×10^9	95.4 (77.61)	9.22	5.6×10^{10}	95.8 (78.17)
CD(p=0.05)	21.974		2.211	1.990		2.270

*The data in parenthesis are arsine transformed prior to analysis.

TABLE 23

Effect of incubation period on mass multiplication of *Trichoderma harzianum*

Incubation period (in days)	Sorghum grains			Mushroom extracts (20%)		
	Total biomass (g kg^{-1} dry substrate)	Spore production (x 10^{10} spores g^{-1} dry substrate)	Per cent viable spores	Total biomass g (g L^{-1} dry substrate)	Spore production (x 10^{10} spore g^{-1} dry substrate)	Per cent viable spores
5	296.8	2.5	69.3 (56.35)	5.2	3.6	70.6 (57.17)
10	450.3	4.2	85.4 (67.54)	8.3	4.4	87.4 (69.21)
15	507.8	5.3	92.6 (74.21)	9.4	5.4	93.5 (75.23)
20	526.8	5.	98.2 (82.29)	10.52	6.2	98.9 (83.98)
25	542.5	6.7	95.3 (77.48)	11.4	7.2	96.8 (79.86)
30	554.1	5.9	92.7 (74.32)	12.3	6.9	94.3 (76.19)
35	566.3	5.2	90.4 (71.95)	12.9	5.8	90.8 (72.34)
40	568.4	5.0	82.8 (65.05)	13.2	5.2	84.6 (66.89)
CD (p=0.05)	30.795	0.845	1.765	2.285	0.915	2.218

*The data in parenthesis are arsine transformed prior to analysis.

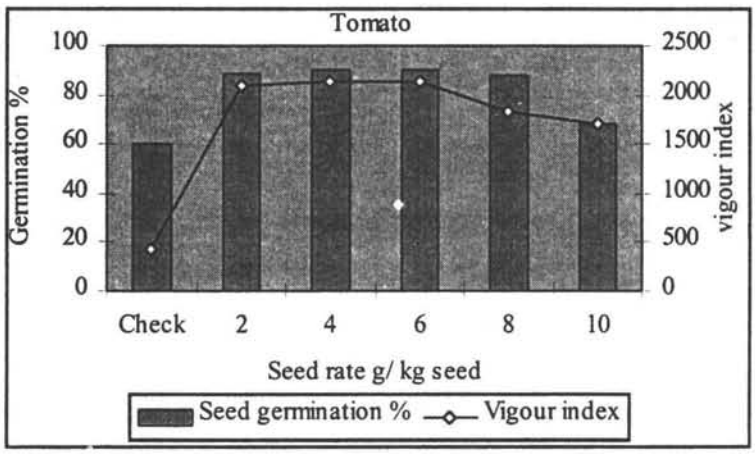


Figure 7b : Effect of doses of bioformulation on seed germination and plant vigour index of tomato

TABLE 24

Effect of storage period and temperature on shelf life of bioformulation

Storage period (in month)	Spore viability on sorghum substrate at different temperature			Spore viability on mushroom extracts at different temperature		
	5°C	25°C	30± 5°C	5°C	25°C	30± 5°C
0	95.4(77.61)	95.4(77.61)	95.4(77.61)	95.8(78.47)	95.8(78.17)	95.8(78.17)
1	95.1(77.21)	93.5(75.23)	91.2(72.74)	95.4(77.61)	94.5(77.75)	91.8(73.36)
2	94.6(76.56)	92.3(73.89)	87.2(69.04)	95.1(77.21)	93.8(75.58)	87.9(69.44)
3	93.5(75.35)	90.4(71.95)	83.4(65.96)	94.5(76.44)	92.4(74.00)	84.4(66.74)
4	92.3(73.89)	89.7(71.23)	80.2(63.58)	93.8(75.58)	90.6(72.15)	80.8(64.01)
5	91.2(72.74)	88.9(70.54)	76.1(60.73)	92.6(74.21)	88.8(70.45)	77.0(61.34)
6	90.2(71.76)	84.2(66.58)	70.2(56.91)	91.5(73.05)	85.5(67.62)	72.5(57.48)
7	89.2(70.81)	80.4(63.72)	66.1(54.39)	90.1(71.76)	81.4(64.45)	66.9(54.88)
8	85.5(67.62)	77.2(61.48)	61.7(51.77)	89.7(71.23)	78.2(62.17)	62.5(52.24)
9	82.2(65.05)	70.8(57.29)	56.6(48.79)	86.3(68.28)	72.5(58.37)	57.8(49.49)
10	80.6(63.87)	62.2(52.06)	51.2(45.69)	85.2(67.37)	64.6(53.49)	53.0(46.72)
11	76.4(60.94)	50.2(45.11)	48.3(44.03)	79.5(63.08)	52.2(46.26)	49.4(44.66)
12	62.1(51.41)	40.5(39.51)	38.4(38.29)	65.8(54.21)	43.7(41.38)	40.2(39.35)
CD (p=0.05)	Storage period =2.56; Temperature=3.52; Storage period x Temperature= 3.29			Storage period =2.88; Temperature=3.89; Storage period x Temperature= 4.92		

*The data in parenthesis are arsine transformed prior to analysis.

SOME CASE EXAMPLES FOR BIOMANAGEMENT AGAINST IMPORTANT PATHOGENS OF VEGETABLE CROPS

Sclerotium rolfsii Sacc. (teleomorph *Athelia rolfsii* (Curzi) Tu & Kimbrough) is a devastating soil-borne plant pathogenic fungus with a wide host range. The disease caused by *S. rolfsii* is a severe problem of almost all crops in India and it is controlled particularly by the use of fungicides. The fungus does not produce asexual spores, over winters in soil and on plant debris as sclerotia. The purpose of this study was to characterize the field isolates of *S. rolfsii* collected from different hosts and locations and also to observe the effect of *Trichoderma harzianum* and *T. viride* isolates available in the laboratory. Cultural, morphological, mycelial compatibility, sclerotium formation and pathogenicity studies were made in ten field isolates of *S.rolfsii*. Mycelial compatibility was the major trait to differentiate the isolates, which were paired in culture in all possible combination (Sharma *et al* 2004a). On the basis of intermingling and interaction zones that developed in the pairing, the isolates were assigned to mycelial compatibility groups (MCG's). Within a compatibility group, all isolates grew together when paired and the hyphae intermingled with little or no cell death. Isolates within a MCG also varied in mycelial and sclerotium morphology. These MCGs also exhibited differential response against twelve biologically effective isolates of *Trichoderma harzianum* and *T. viride* in the form of mycelial growth and sclerotia formation, clearly highlighting the variability in biological activity of *Trichoderma* spp. against *S. rolfsii* isolates (Sharma *et al* 2004a) (Table 25, 26).

TABLE 25

Mycelial growth inhibition of *Sclerotium rolfsii* isolates by different isolates of *Trichoderma* spp

Trichoderma isolate	*S.rolfsii* isolates									
	SR-1	SR-2	SR-3	SR-4	SR-5	SR-6	SR-7	SR-8	SR-9	SR-10
1	2	3	4	5	6	7	8	9	10	11
TH-3	76.1	86.3	88.0	80.1	82.2	88.1	75.1	85.2	72.2	79.1
	(60.7)	(68.3)	(69.7)	(63.5)	(65.1)	(69.8)	(60.1)	(67.4)	(51.2)	(62.8)
TH-10	52.1	82.2	33.7	75.3	77.1	84.9	68.1	32.2	71.4	54.6
	(46.2)	(65.1)	(35.5)	(60.2)	(61.4)	(67.2)	(55.6)	(34.6)	(57.6)	(47.6)
TH-30	50.2	76.1	49.4	65.3	64.3	78.6	71.9	47.3	73.2	52.3
	(45.1)	(60.7)	(44.5)	(53.9)	(53.3)	(62.4)	(57.4)	(44.0)	(68.8)	(46.3)
TH-31	45.3	72.1	61.5	50.1	51.9	77.1	72.5	60.2	77.6	47.0
	(42.3)	(58.1)	(51.7)	(45.1)	(46.2)	(61.3)	(58.4)	(50.9)	(61.8)	(43.3)
TH-AG	64.1	50.3	70.6	54.2	53.1	51.3	66.5	68.3	71.3	67.1
	(53.2)	(45.2)	(57.2)	(47.4)	(46.8)	(45.8)	(54.6)	(55.7)	(57.5)	(55.0)
TV-2	75.2	0.0	61.9	15.3	16.2	0.0	27.3	60.5	7.9	79.9
	(60.1)	(0.0)	(51.9)	(23.0)	(23.7)	(0.0)	(31.5)	(51.0)	(16.2)	(63.4)

Contd...

...Contd.

1	2	3	4	5	6	7	8	9	10	11
TV-4	27.2	8.2	53.3	6.3	6.8	8.9	26.4	52.2	7.2	28.9
	(31.4)	(16.6)	(46.9)	(14.5)	(15.1)	(17.4)	(30.9)	(46.2)	(15.5)	(32.5)
TV-12	0.0	0.0	61.5	0.0	0.0	0.0	69.8	59.3	0.0	0.0
	(0.0)	(0.0)	(51.7)	(0.0)	(0.0)	(0.0)	(56.7)	(50.4)	(0.0)	(0.0)
TV-15	81.3	69.1	58.6	72.2	73.2	70.3	58.7	56.3	32.1	80.0
	(64.4)	(56.2)	(49.9)	(58.2)	(68.8)	(57.0)	(50.0)	(48.6)	(34.5)	(63.5)
TV-32	75.2	37.4	63.6	40.4	41.3	38.8	7.7	61.8	14.2	76.9
	(60.1)	(37.1)	(52.9)	(39.5)	(40.0)	(38.6)	(16.0)	(51.8)	(22.1)	(61.3)
TV-CHEN	68.1	14.6	68.2	35.2	30.2	15.6	4.9	66.4	27.0	70.4
	(55.6)	(22.6)	(55.7)	(36.4)	(33.3)	(23.3)	(12.7)	(54.6)	(31.4)	(57.0)
TV-NIR	80.2	16.1	67.6	50.2	48.3	17.8	5.2	65.8	16.9	82.3
	(63.6)	(23.7)	(55.3)	(45.1)	(44.0)	(25.0)	(13.2)	(54.2)	(24.2)	(65.1)

CD (at p± 0.05) TH isolates=1.544; SR isolates= 0.772; and TH x SR=4.882

TABLE 26

Sclerotial growth inhibition of *Sclerotium rolfsii* isolates by cell free culture filtrate of *Trichoderma* spp

Trichoderma	*S.rolfsii* isolates									
isolate	SR-1	SR-2	SR-3	SR-4	SR-5	SR-6	SR-7	SR-8	SR-9	SR-10
1	2	3	4	5	6	7	8	9	10	11
TH-3	65.3	41.3	80.3	83.1	81.3	40.9	60.3	83.1	82.3	62.3
	(53.9)	(40.0)	(63.7)	(65.7)	(64.4)	(39.8)	(50.9)	(65.7)	(65.1)	(52.1)
TH-10	61.3	50.3	52.7	60.2	62.2	49.1	70.2	60.2	56.3	59.3
	(51.5)	(45.2)	(46.6)	(50.9)	(52.1)	(44.5)	(56.9)	(50.9)	(48.6)	(50.4)
TH-30	39.2	31.3	40.3	42.2	40.1	30.1	45.3	42.2	60.3	35.3
	(38.1)	(33.8)	(39.4)	(40.5)	(39.3)	(33.3)	(42.3)	(40.5)	(50.9)	(36.5)
TH-31	48.2	36.2	34.2	38.2	35.2	35.2	53.2	38.2	57.2	45.2
	(43.9)	(37.0)	(35.8)	(38.2)	(36.3)	(36.3)	(46.8)	(38.2)	(49.1)	(42.3)
TH-AG	51.8	47.3	70.1	72.2	71.9	48.1	60.1	72.2	65.2	50.2
	(46.0)	(43.5)	(56.9)	(58.2)	(58.0)	(43.9)	(50.3)	(58.2)	(53.9)	(45.1)
TV-2	34.3	32.3	34.1	38.3	40.3	30.2	43.1	38.3	52.1	32.2
	(35.9)	(34.6)	(35.7)	(38.2)	(39.4)	(33.3)	(41.0)	(38.2)	(46.2)	(34.6)
TV-4	38.1	34.2	30.2	34.2	38.2	31.2	40.1	34.2	39.2	34.2
	(38.1)	(35.7)	(33.3)	(35.7)	(38.2)	(34.0)	(39.3)	(35.8)	(38.8)	(35.7)

Contd...

...Contd.

1	2	3	4	5	6	7	8	9	10	11
TV-12	40.3	45.3	62.2	65.4	69.1	43.2	60.2	65.4	40.3	39.1
	(39.4)	(42.3)	(52.1)	(54.0)	(56.2)	(41.0)	(50.9)	(54.0)	(39.4)	(38.7)
TV-15	47.8	57.3	70.3	72.2	62.5	55.3	50.2	72.2	52.9	45.4
	(43.7)	(49.2)	(57.0)	(58.2)	(52.2)	(48.0)	(45.1)	(58.2)	(46.7)	(42.4)
TV-32	38.6	45.3	52.3	55.2	50.4	44.2	50.9	55.2	39.1	35.2
	(38.4)	(42.3)	(46.9)	(48.0)	(45.2)	(41.7)	(45.7)	(48.0)	(38.7)	(36.4)
TV-CHEN	43.0	44.2	53.2	54.3	51.2	42.2	48.2	54.3	50.7	42.2
	(41.0)	(41.7)	(46.8)	(47.5)	(46.3)	(40.5)	(44.0)	(47.5)	(45.4)	(40.4)
TV-NIR	45.9	52.2	65.1	69.2	68.1	50.1	51.2	69.2	35.2	43.3
	(42.7)	(46.3)	(53.8)	(56.3)	(55.6)	(45.0)	(45.7)	(56.4)	(36.4)	(41.6)

CD= (at p± 0.05) TH isolates=1.655, SR isolates= 0.827 and TH x SR=5.233

Biological Management of Die Back and Fruit Rot of Chilli (*Capsicum annum* L.) caused by *Colletotrichum capsici* (Syd.) Butler and Bisby

Chilli anthracnose caused by *Colletotrichum capsici* (Syd.) Butler and Bisby appears in Delhi region soon after heavy rainfall in first and second week of August persisting almost for 100-120 days in the field and continue in transit and storage. To break the life cycle of the pathogen at early stage of the disease development, studies on the effect of different formulations of *Trichoderma harzianum* Rifai isolates, Neemarin and neem oil were used on two chilli cultivars i.e. Pusa Sadabahar and Navjyoti. *T. harzianum* (toxin) suppressed the symptom expression, conidial germination and mycelial growth of *C. capsici* upto 100 per cent. Application of three different formulations of *T. harzianum* i.e. partially purified toxin, sorghum, and talc base (dry powder) applied in the field from the beginning i.e. seed, seedling followed by foliar spray in combination with Neemarin (neem product) and neem oil reduced the disease intensity upto 60.0 and 56.5 per cent in Pusa Sadabahar and Navjyoti, respectively was noticed. Similarly fruit rot was also reduced upto 63.7 and 46.8 per cent in Pusa Sadabahar and Navjyoti, respectively. The preventive spray of *T. harzianum* in combination with Neemarin and neem oil should be given early in the morning at the initial stage of the disease development (first week of August) to wash off the due deposit when the temperature ranges from 28-30°C and RH 100 per cent (favorable for disease development) and should continue at 10 days interval till harvest. One pre harvest spray of *T. harzianum* two days before the harvesting should be followed to reduce the post-harvest and storage losses caused by *C. capsici*. (*Sharma et.al* 2004b).

TABLE 27

Schedule of *T. harzianum* formulation treatments along with Neemarin and neem oil on chilli varieties against anthracnose

Crop stage	Operations
Before Nursery Sowing	Soil solarization
	Application of NSKE @ 50 g / sq.m
Seed Treatment	*T. harzianum* @ 2 g/kg seeds
Nursery	Covered with nylon net
Before Transplanting	Seedling dip in *T harzianum* @ 2 g/l
Transplanted crop	Spraying of
14 DAT	*T. harzianum* (Toxin) spray 10ml /l
24 DAT	Neemarin @ 4 % (plant product)
34 DAT	*T. harzianum* .
44 DAT	Neemarin @ 4 %
54DAT	*T. harzianum* (Toxin) spray @ 10ml /l
64DAT	Neemarin @ 4 %
74DAT	*T. harzianum* (Toxin) spray @ 10ml /l
84DAT	Neem oil @ 0.05% (plant product)
94DAT	*T. harzianum* (Toxin) spray 10ml /l.
104DAT	Neem oil @ 0.05%
107DAT(two days before harvesting)	*T. harzianum* (Toxin) @ 10ml /l + Neemarin @ 4 %
Harvesting (109 DAT)	

Total no. of sprays =12 (6 bioagents + 6 plant products) [DAT = Days After Transplanting]

TABLE 28

Effect of different formulations of *T. harzianum* on conidial germination and mycelial growth of *C. capsici* in *in vitro*

Treatments (conc.)	Per cent germination	Per cent inhibition of conidia over control	Mycelial growth (mm)	Per cent mycelial growth inhibition
Th toxin (1%)	3.4	96.3	3.0	97.0
Sorghum (0.2%)	9.0	90.5	6.2	93.8
Talc (0.4%)	13.4	86.1	10.0	90.0
Control	95.1	–	100.0	–
CD = 0.05	3.5		0.4	–

* Mean of five replications.

TABLE 29

Effect of *T. harzianum* formulations on dieback and fruit rot of chilli in pot culture during 2002 and 2003 (Pooled data)

Variety	Treatments	Per cent disease intensity of dieback	Per cent disease control	Per cent disease intensity of fruit rot	Per cent disease control
Pusa	Th toxin (1%)	39.5*(38.9)	39.60	37.5 (37.8)	44.36
Sadabahar	Sorghum (0.2%)	43.0 (40.9)	34.25	46.1 (42.8)	31.60
	Talc (0.4%)	49.2 (44.5)	24.77	50.3 (45.2)	25.37
	Control	65.4 (53.9)	—-	67.4 (55.2)	—-
CD(P=0.05)		0.6		0.5	
Navjyoti	Th toxin (1%)	30.0 (33.2)	48.5	28.1(32.0)	53.5
	Sorghum (0.2%)	34.1 (35.7)	41.5	33.4 (35.3)	44.7
	Talc (0.4%)	41.2 (39.9)	29.3	39.6 (39.0)	34.4
	Control	58.3 (49.7)	—-	60.4 (51.0)	—-
CD(P=0.05)		0.4		0.4	

* Mean of pooled data of two years 2002 and 2003 with five replications

Figures in parentheses are arc sine transformed values

Table 30

Effect of different formulations of *T. harzianum* in combination with Neemarin and neem oil on dieback and fruit rot of chilli under field conditions during 2002 and 2003 (Pooled data)

Treatment	Per cent disease intensity of dieback		Per cent disease intensity fruit rot		Yield Q/ha
	Mean*	PDC	Mean*	PDC	
		Pusa Sadabahar			
Th toxin (1%)	19.5 (26.1)	61.05	24.0 (29.3)	63.7	27.4
Sorghum (0.2%)	22.2 (28.0)	55.65	31.2 (33.9)	52.9	26.0
Talc (0.4%)	27.9 (31.9)	44.10	38.8 (38.5)	41.6	25.1
Control	50.0 (45.0)	—-	66.4 (54.5)	—-	23.2
CD (P=0.05)	0.2		0.1		0.1
		Navjyoti			
Th toxin (1%)	17.9 (25.0)	56.5	26.2 (30.7)	46.8	29.9
Sorghum (0.2%)	21.4 (27.5)	48.2	27.7 (31.8)	43.7	27.6
Talc (0.4%)	25.7 (30.4)	37.7	28.4 (32.2)	42.2	26.9
Control	41.2 (39.9)	—-	49.2 (44.5)	—-	25.2
CD (P=0.05)	0.4		0.1		0.1

* Mean of pooled data of two location and years 2002 and 2003 with three replications

Figures in parentheses are arc sine transformed values

TABLE 31

Effect of different formulations of *T. harzianum* on post-harvest fruit rot during 2002 and 2003 (Pooled data)

Treatments	Symptoms appearance DAH*	Per cent healthy fruits*	Per cent disease intensity*
Th toxin (1%)	12.2	89.8 (71.3)	10.5 (18.9)
Sorghum (0.2%)	10.7	74.3 (59.5)	15.9 (23.4)
Talc (0.4%)	8.4	65.9 (54.3)	30.1 (33.3)
Control	4.5	31.5 (34.1)	68.5 (55.9)
CD (P=0.05)	0.3	1.2	2.6

DAH = Days After Harvest

* Mean of pooled data of two locations and years 2002 and 2003 with three replications. Figures in parentheses are arc sine transformed values

MODE OF ANTAGONIST APPLICATION

Most of the biocontrol agents are usually applied as–

- Soil application
- Seed coating
- Foliar spray

Soil Application

The granule formulation of the biocontrol agents has been developed specially for the soil application. Sometimes it can be placed near the root zone along the seedlings during transplanting. The granular formulation of *Trichoderma*, and *Gliocladium* is commonly used. Even the powder formulation based on talc or charcoal may be applied with well-decomposed farmyard manure (FYM) or composts. For example, the application of *Trichoderma* has been recommended @ 1 kg talc based formulation mixed with 25 kg FYM and broadcast over the soil surface per acre against soil borne pathogens, i.e. *Rhizoctonia Pythium, Fusarium, Sclerotinia* and *Sclerotiorum* infection. For nursery beds, drenching of 0.5-1.0 percent bioformulation (5 to 10g/litre water) is applied just after sowing of seeds or transplanting.

The soil application of antagonist needs a large amount of inoculum, therefore, it is recommended mostly for the nursery beds or transplanting of the seedlings, particularly of horticultural and agro-forestry crops.

Seed Coating

The seed application of biocontrol agents is quite convenient, as little amount of inoculum is required to disperse it along the seed surface. Seed treatment may be given as a dry seed treatment, wet seed treatment, and slurry seed treatment.

In case of dry seed treatment, the powder formulation of biocontrol agents is required. Generally, 6-10 g/kg seed of formulation is used. The addition of stickers like carboxy methyl cellulose @ 1 per cent will be helpful for the proper dispersal of inoculum.

For wet seed treatment, the formulation of biofungicides is suspended in the water and seed is dipped from 10 to 30 minutes. Sometimes the time for dipping may be increased. After treatment, drying of seeds in shade is usual practice before sowing. Certain stickers or nutrient based adjvants may be applied along with bioformulations. Singh *et al.* (2000) used 100 g wet formulation of *Trichoderma viride* suspended in 10 litres of water along with 2 per cent molasses for the control of black scurf of potato. In slurry application, the bioagent in powder form mixed with water to form the slurry and the required quantity of seed was mixed in the slurry and dried in shade. The method of treatment ensures greater amount of inoculum on the seed surface. Seed coating / bacterization is recommended to those biocontrol agents, which have *sufficient* rhizosphere competance so that they may proliferate easily in rhizosphere, increased to sufficient number to express the biocontrol potentiality, mainly. In general bioagents like *Pseudomonas* or *Bacillus* are applied through seed bacterization.

Foliar Application

The foliar application of biocontrol agents is comparatively less common as compared to seed or soil application. However, for the biocontrol of certain aerial plant pathogens the wet formulation is suspended and applied through spraying. In case of biocontrol of bacterial blight of rice the spray method of fluorescent *Pseudornonus* was found effective to reduce the disease intensity (Singh. 2000). In case of vegetable crops foliar spray has also been found effective against anthracnose or die back of chillies; (Sharma et. al 2004b).

The method for dispersal of BCAs may be selected according to specific crop system and pathogen as also recommended four methods; of dispersal for the *Trichoderna* application i.e. broadcast, furrow, root zone and seed coating. It was emphasized that these methods that introduce the antagonists with planting material are more economical.

MECHANISM OF BIOLOGICAL CONTROL

How best we define the biological control but basically researches conducted till today are based on the disease control and growth promotion. Amongst the most usable and practical approach of biocontrol mechanism is Induced Resistance. The other mechanisms of biological control are antibiosis, mycoparasitism and competition which are still referred as possible mechanisms. Therefore, we need to understand the mechanisms underlying biologically induced resistance and biological control.

With the upcoming new biotechnological and molecular biological approaches, the plant disease managers are trying to reshape or rather say develops disease management strategies based on new technologies. Current concern about the environment indicates a need to limit application of chemicals for plant disease control and therefore, in this scientific renaissance, very importantly are coming two encouraging concepts; Biological control and induced resistance. These are the most encouraging techniques for plant protection. There are a variety of terms used to describe the phenomenon of induced plant immunization, induced systemic resistance (ISR) and systemic acquired resistance (SAR). Traditionally, the term IR had been used by entomologists and ISR and SAR by phytopathologists, each having the same meaning. Advancements in the biological control of plant diseases using microbial agents contribute directly to the development of biological control of plant diseases using microbial agents contribute directly to the development

of biological control products for improved plant health, but also indirectly through the identification of promising physiological or molecular strategies.

The induced responses were highly ignored by the general scientific community as a tool to manipulate plant resistance to control diseases. A systematic definition is not yet understood, as the phenomenon. though, induced resistance is only one of several types of resistance to microbial disease that flowering plants process. The other major categories are basic resistance, organic specific, age related and parasite specific resistance. Induced resistance differs from other types of resistance as its expression relies on some previous treatment of the plant that sensitizes it so that what should be susceptible tissue resists invasion by parasites that previously were successful pathogens. A single induction treatment can elicit resistance to a wide variety of parasites and in this lack of specificity; induced resistance resembles basic resistance more than parasite-specific resistance. Indeed, induced, age-related and organ-specific resistance do not require the presence of known parasite-specific genes for resistance against the parasite in question, although some forms of parasite-specific resistance may also be age-related in that are only expressed at a certain stage of plant development (Bhattacharya and Ward, 1986).

Induced resistance is distinguished from conventional chemical as well as biological procedures in plant protection by the lack of toxicity of the inducing agents towards the pathogens. The protection of the plants is not based on the elimination of the pathogens but rather on the activation of plant defense mechanisms or on the enhancement of their activity. The basic idea behind induced resistance is that genes for resistance or defense reactions exist in all the plant is not based on the elimination of the pathogens but rather on the activation of plant defense mechanisms or on the enhancement of their activity. The basic idea behind induced resistance is that genes for resistance or defense reactions exist in all plants. These genes are not expressed until after a resistance inducing treatment activates or enhances their expression, or that changes in the plant metabolism modify the activity of such genes. Induced resistance is considered to be a biological plant protection procedure in which the plant is the target of the procedure, not the pathogens.

DISEASE SUPPRESSION

The known bioagents, defined by the researchers are mainly fungal and bacterial in origin. The key feature to demonstrate the existence of SAR or JSR is that the subsequent challenge with a pathogen is either spatially separated form the inducing inoculation or, if the challenge is at the same position as the inducing inoculation that a period elapses where novel genes are switched on and characteristic resistance moieties are produced. Unfortunately, most of the work on induced resistance has concerned foliar pathogens and only relatively recently has the potential of this mechanism been recognized for biocontrol of soil-borne pathogens. Consequently, in contrast to the vast literature covering induced resistance in relation to the control of foliar pathogens, unequivocal examples of SAR or ISR involving soil-borne pathogens are rare. Using split root systems, both bacteria and fungi have been shown to induce resistance in several plants when applied to roots. For example, *Pseudomonas pulido* 89B-27 and *Serratia marcescens* 90-166 induced systemic resistance to *Fusarium oxysporum f sp cucumerinum* in cucumber (Liu *et al.*,

1995a,b);' *Pseudomonas corrugata and Pseudomonas fluorescens* induced systemic resistance to *Pythium aphanidermatum* in cucumber (Zhou and Paulitz, 1994): and *P. fluorescens* induced systemic resistance to *F oxysporum f sp. raphanii* in radish (Leeman *et al.*, 1995a,b), with lipopolysaccharide of the bacterial wall strongly implicated as being involved in the induction process. Similarly, non-pathogenic *Fusarium oxysporum* isolates induced resistance to *F. oxysporum f sp. cucumerinum* in cucumber *F. oxysporumf sp. dianthi* induced resistance to *F oxysporium fsp. lycopersici* in tomato (Kroon *et al.*, 1991). In an alternative treatment, inoculation of the first true leaves of cucumber with *Colletotrichum orbiculare* or tobacco necrosis virus resulted in induced resistance to *F. oxysporum f sp. cucumerinum* on the roots.

The phenomenon of treating seeds, roots or cuttings with inducing bacteria or fungi and achieving induced resistance to subsequent stem or foliage challenge by a range of viral, bacterial and fungal pathogen is also known (Alstrom 1991), Liu *et al.*, 1992, 1995a,b; Meera *et al.*, 1994, 1995), suggesting an important role for induced resistance in biocontrol in general. There are few data on the molecular and biochemical changes occurring in roots as a result of induced resistance, although phytoalexins and peroxidases are thought to be involved in the response of carnation root to inoculation with *Pseudomonas* (Van Peer *et al.*, 1991]; Van Peer and Schippers, 1992) and pathogenesis-related proteins were synthesized in roots and leaves of cotton plants following inoculation with arbuscular mycorrhiza fungi (Liu *et al.*, 1995b). Based on studies from other SAR systems, responses may involve accumulation of antimicrobial low molecular weight chemicals such as phytoalexins, formation of protective layers via accumulation of polymers such as lignin, callose and hydroxyproline-rich glycoproteins, increases in activators of enzymes leading to the production of such materials, and increases in the amount of chitinases, β-1,3 glucanases, peroxidases and other pathogenesis-related proteins.

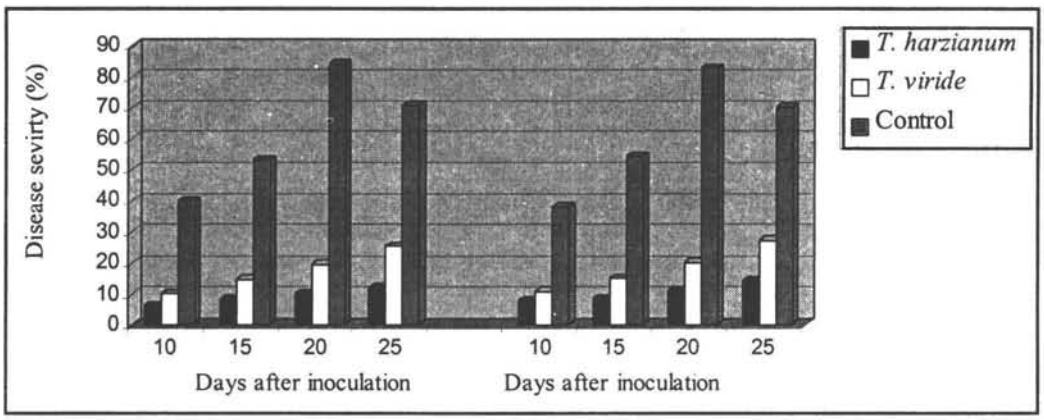
In a study conducted in an intact host-pathogen interaction among cauliflower, tomato and *Trichoderma* species at Division of Plant Pathology IARI by the author the two *Trichoderma* species namely *T. harzianum* and *T. viride* were used against *Sclerotinia sclerotiorum* infection was consistently reduced after a prior *T. harzianum* and *T. viride* treatment on plant parts spatially separated from the site of S. *sclerotiorum* inoculation. *T. harzianum* and *T. viride* seedling treatment reduced *S. sclerotiorum* stem and leaf infection in cauliflower and tomato. Though, the suppression in disease index was slightly greater in *T. harzianum* than that of *T. viride* treatment and cauliflower than that of tomato. Because in the these experiments *Trichoderma* species could not directly interact with S. *sclerotiorum* or affect the environment for S. *sclerotiorum* development for reasons of spatial separation, induction of systemic resistance is, by exclusion of alternatives, the most likely explanation of the S. *sclerotiorum* control. Moreover, the observed phenomenon shares other characteristics with ISR. First of all, *Trichoderma* spp not only effective against *S. sclerotiorum* but also worked, as like Induced Systemic Resistance and Systemic Aquired Resistance (Ryals *et al.*, 1997) against several pathogen. *T. harzianum* seedling treatment reduced anthracnose symptoms of *Colletotrichum lindemuthianum* in bean, gray mould of *Botrytis cinerea* in tomato, lettuces, pepper, bean and tobacco and also reduced white mould in lettuce. Finally, the effect of *Trichoderma* spp seedling treatment needed, just like ISR, some times to develop in the host plant. The S. *sclerotiorum* was only efficiently controlled when inoculated one or more days after *Trichoderma* species treatment) compared with pathogen-induced systemic resistance this lag period of one day is rather short but nonetheless

possible. Since Smith *et al.* (1991) detected systemic resistance one day after inoculation with *Pseudomonas syringae* pv. *syringae*. However, the real lag period for induction of systemic resistance by *Trichoderma* species could be more than one day because *S. sclerotiorum* infections might still be affected by induced resistance during this slow initial development. In this case the induced resistance that developed after the *S. sclerotiorum* inoculation probably came too late to suppress spreading blackening formulation, but managed to delay the infection. On the other hand *Trichoderma* species treated leaves the modes of action like competition for nutrients and suppression of *S. sclerotiorum* pathogenicity enzymes, can be involved in S. *sclerotiorum* control (Sharma and Sain 2003).

TABLE 32

Influence of *Trichoderma harzianum* and *T.viride* application site on *Sclerotinia sclerotiorum* infection in cauliflower and tomato. *Trichoderma* strain was applied to seedling and /or first leaves of three weeks old plants and /or through seed and/or seedling treatment. One week later the trifoliate /leaves were inoculated with *S.sclerotiorum*. Infection was evaluated 5 days after inoculation

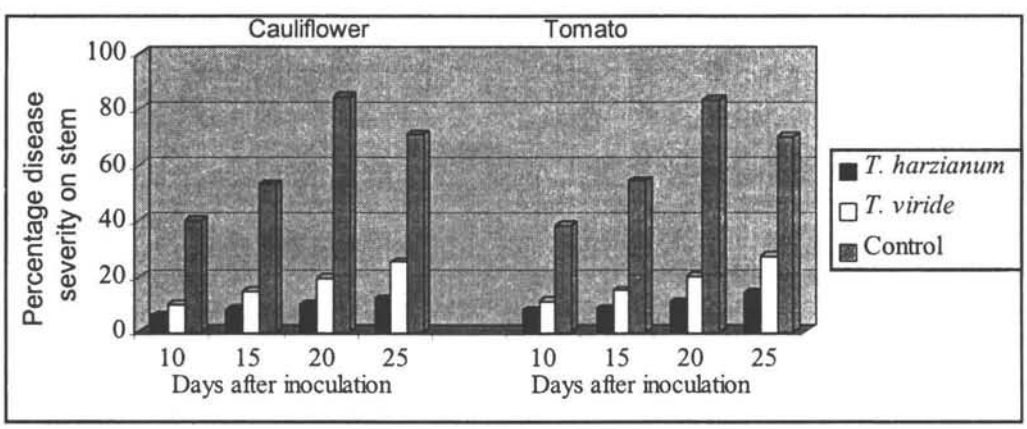
Treatments	Per cent disease severity*			
	Tomato		Cauliflower	
	Th	Tv	Th	Tv
Leaf	38.13	39.23	39.35	40.97
	(38.52)	(38.80)	(38.25)	(39.80)
Seedling + Seed	16.23	17.64	17.57	18.56
	(23.73)	(24.80)	(24.73)	(25.50)
Seedling + Leaf	32.31	34.54	33.86	35.45
	(34.63)	(35.98)	(35.55)	(36.58)
Seed + Leaf	14.12	15.42	16.56	17.67
	(22.06)	(23.11)	(23.97)	(24.80)
Seedling + Seed + Leaf	11.64	13.26	13.38	14.56
	(19.91)	(31.35)	(21.42)	(22.40)
Untreated control	50.34	53.86	53.35	55.35
	(45.17)	(47.18)	(46.91)	(48.07)
CD (p=0.05)				
Treatment	3.46		4.32	
Isolate	0.12		0.15	
Treatment x isolate	1.02		1.12	



Each bar is the mean of 6 replications. Bars with the same letter do not differ significantly at P = 0.05 by fisher's protected LSD test.

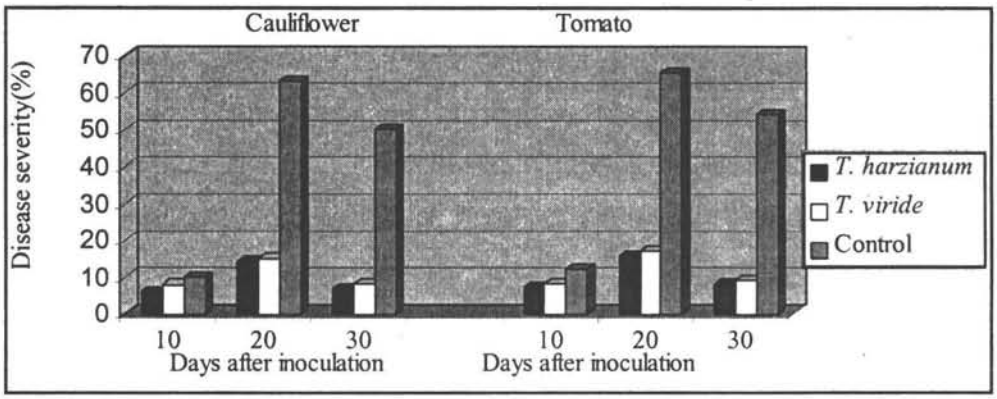
Figure 8 : Effect of *Trichoderma harzianum* and *T. viride* seedling treatment on *Sclerotinia sclerotiorum* disease severity in the canopy of cauliflower and tomato. *Trichoderma* was applied 7 days before plants were inoculated with *S. sclerotiorum*

DISEASE SEVERITY ON STEM (% COVERAGE)



Each bar is the mean of 6 replications. Bars with the same letter do not differ significantly at P = 0.05 by fisher's protected L SD test

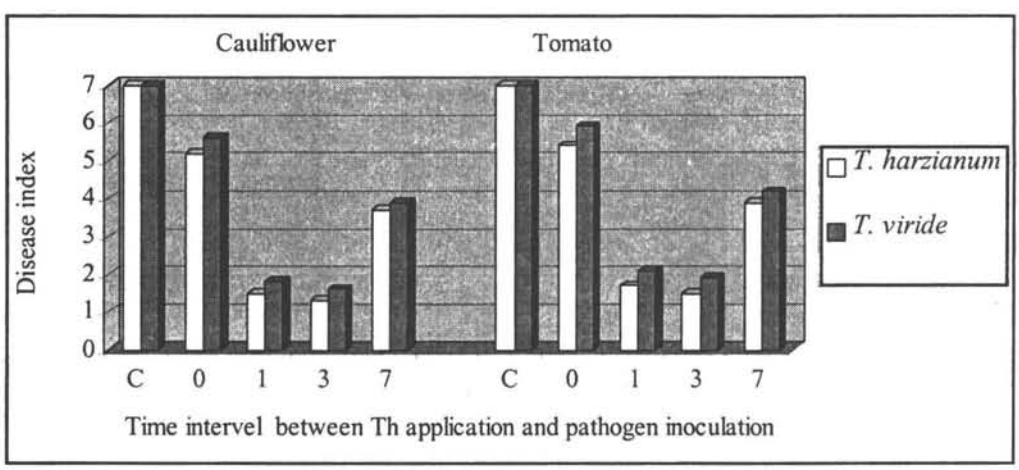
Figure 9 : Effect of *Trichoderma harzianum* and *T.viride* seedling treatment on stem in cauliflower and tomato. *Trichoderma* was applied 7 days before *S. sclerotiorum* inoculation and symptoms were evaluated at various time points after inoculation



Each bar is the mean of 6 replications. Bars with the same letter do not differ significantly at P = 0.05 by fisher's protected LSD test

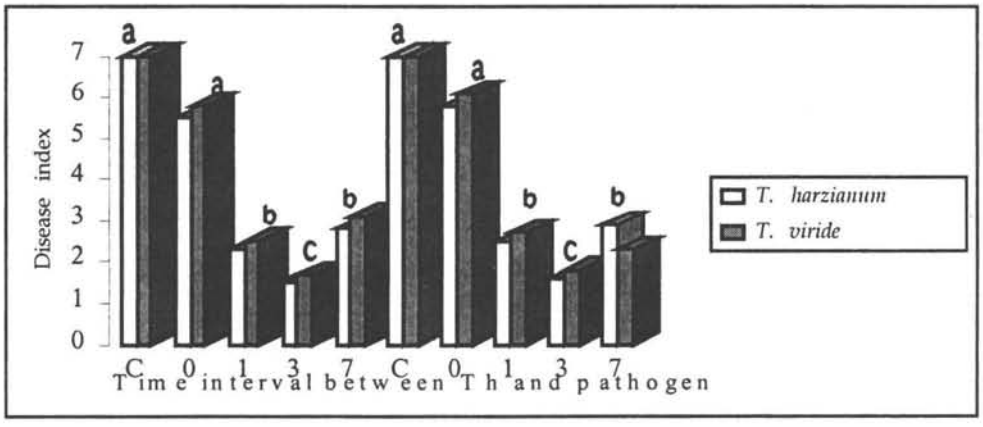
Figure 10: Effect of *Trichoderma harzianum* and *T.viride* seedling treatment on deleafing caused by *S. sclerotiorum* in cauliflower and tomato. *Trichoderma* was applied 7 days before *S. sclerotiorum* inoculation and symptoms were evaluated at various time points after inoculation. Each bar is the mean of 6 replications.

Deleafing (% of leaves)



Each bar is the mean of 6 replications. For each time point after infection, bars with the same letter do not differ significantly at P = 0.05 by fisher's protected LSD test.

Figure 11 : Influence of *Trichoderma harzianum* and *T. viride* application site and time on *Sclerotinia sclerotiorum* infection in cauliflower and tomato *Trichoderma* was applied to the seedling later challenged with *S. sclerotiorum.* Disease severity was evaluated 14 days after inoculation according to a 0-7-disease index.



Each bar is the mean of 6 replications. For each time point after infection, bars with the same letter do not differ significantly at P= 0.05 Fisher's LSD test.

Figure 12 : Influence of *Trichoderma harzianum* and *T. viride* application site and time on *Sclerotinia sclerotiorum* infection in cauliflower and tomato *Trichoderma* was applied to leaves later challenged with *S. sclerotiorum*. Disease severity was evaluated 14 days after inoculation according to a 0-7-disease index.

GROWTH PROMOTION

Over the last 20 years, there have been an increasing number of reports of promotion of plant growth following treatment of seeds, roots, cuttings, soil or artificial growing media with bacteria and fungi, particularly species of *Pseudomonas* and *Trichoderma*. Depending on the plant studied, growth promotion has been expressed in a variety of ways but most commonly as increases in germination, emergence fresh or dry weight of roots or shoots, root length, yield and flowering. Many aspects of this phenomenon have been reviewed in detail several times (Weller, 1988; Baker, 1989; Kloepper *et al, 1989,* 1991; lnbar *et al.,* 1994; Ryder *et al.,* 1994) and numerous large screening studies have been carried out specifically to search for such plant growth-promoting microorganisms. Indeed, the term plant growth-promoting rhizobacteria (PGPR) has been coined specifically to describe bacteria which colonize roots and have the ability to stimulate plant growth and this has led to a new area of work (Ryder *et al.,* 1994).

Frequently, growth promotion has involved application of known biocontrol agents, but even so, the modes of action involved in the plant growth promotion observed have not always been clear. In soils containing major pathogens such as *Gaeumannomyces graminis var. tritici, Pythium spp. and Rhizoctonia spp.* the growth promotion effect may well reflect biocontrol acting through mechanisms such as competition, antibiosis, parasitism and induced resistance, as described earlier. However, growth promotion can still occur in soils or environments lacking such major pathogens (Sharma 2003). It is then thought to be due either to control of minor pathogens such as deleterious rhizobacteria (Baker, 1989) in the same way as major pathogens or to a direct effect on the plant.

Direct effects are commonly thought to be mediated by production of plant hormones such as auxins, cytokinins or gibberellins (Arshad and Frankenberger, 1991). It is difficult to obtain unequivocal evidence for their production in non-sterile soil, although several studies carried out in sterile conditions have implied their involvement. For example, results from a gnotobiotic growth pouch assay showed that *Pseudomonas pulido* GR12-2 consistently induced a significant elongation of roots of canola *(Brassicalnapus)* compared with controls and was associated with enhanced shoot height and phosphorus uptake by roots and subsequent transfer to shoots (Lifshitz *et al.*, 1987). *Pseudomonas pulido* GR 12-2 produced indole-I-acetic acid (IAA) and fixed nitrogen (although at rates 20-fold slower than *Azotobacter vinelandii* based on the acetylene reduction assay, (Hong *et al.*, 1991), which may have influenced plant growth directly. However, in addition it also degraded l-aminocyclopropane-l-carboxylate (ACC), the immediate precursor of ethylene, thereby potentially relieving the normal ethylene-induced inhibition of root development. Similarly, work with corn *(Zea mays),* tomato *(Lycopersicon esculentum)* and tobacco (*Nicotiana tabacum)* cultivars suggested that a growth regulator was produced *Trichoderma* spp. and that this was directly involved with the increased rate of seed germination and weight of shoots and stems following inoculation (Windham *et al.*, 1986 , Sharma 2003).

Associative nitrogen fixation may also occur with *Azospirillum* spp., *Azotobacter spp., Bacillus spp.* possibly some *Pseudomonas* spp. (Kloepper *et al.*, 1989; Hong *et al.*, 1991) to increase plant growth directly. Production of vitamins, conversion of non-utilizable material into a form that can be used by the improved availability and uptake of some minerals may also contribute to the growth promotion phenomenon (Baker, 1989; Klefeld and Chet 1992). Significantly, especially for microbes that are to be commercially the future, it would seem important to understand the mode of action involved in growth promotion to ensure reproducibility of effect.

The above examples very well highlights the induced resistance concept due to the factors explained and therefore it is clear that till today the defined biological control mechanism in field works through IR than other mechanisms. Induced resistance can be elicited in otherwise susceptible plants by the application of living organisms also known as bcas (Kuc 1982) or by abiotic treatments (e.g. Ye *et al.* 1989; Stevens *et al.* 1990), and may be expressed only in the treated tissue or considerably beyond the region of treatment. Localized resistance elicited by prior inoculation with incompatible pathogens can most easily be explained when these pathogens trigger defenses whose effects linger sufficiently to inhibit subsequent infection by a compatible pathogen. The more intriguing examples of induced resistance are those in which the inducing treatment does not directly elicit any of the defenses, such as cell death, phytoalexin accumulation, or detectable cell wall modifications, that usually are thought to account for resistance in genotypically resistant plants. These treatments must elicit other localized for systemic changes that either directly interfere with any subsequent invasion by the parasite, or alter the parasite-plant interaction in favour of the plant That these changes may effect subsequent fungal development is indicated by the fact that, once inside the tissue, fungal growth often appears impaired in comparison with that in unprotected plants (Kovats *et al.* 1991; Ye *et al.* 1992); however, it has yet to be shown that these changes are more important in preventing fungal growth than antimicrobial compounds elicited during fungal infection.

In addition, induced resistance also is commonly characterized by a decrease in the frequency of initial penetration of epidermal cells in association with an increased frequency of localized, modifications of the plant cell wall elicited after fungal inoculation (Kovats *et al.* 1991). Such rapid and localized wall modifications are typical of the expression of basic resistance and it would seem that protected plants may respond more as nonhosts than hosts towards some of their normally successful pathogens. Significantly, compared to normal cucumber plants, protected ones have higher latent activity of membrane-bound *H*.J:glucan synthase (Schmele and Kauss 1990), which may account for the faster appearance of callose containing papillae after fungal challenge of protected plants (Stumm and Gessler 1986; Kovats *et al.* 1991). Moreover, protected plants lignify faster than unprotected plants in response to wounding, probably because of the systemic increase in at least two enzymes, including peroxidase, essential for lignin formation. It seems likely, therefore, that some of the systemic changes induced in protected plants ensure that fungal-induced damage results in rapid, wall-associated modifications that may help prevent further fungal ingress. The probable involvement in induced resistance of several pre-existing and fungal-induced defenses indicates that this form of resistance, like basic resistance (Heath 1991), is multicomponent (Ye *et al.* 1990; Kovats *et al.* 1991).

Interestingly, some of the systemic changes that occurs in a plant after treatments that induce resistance also occur as a plant ages (Fluhr *et al.* 1991); Wyatt *et al.* 1991). This raises the possibility that the mechanisms of induced resistance and some forms of age-related resistance may be similar, a hypothesis supported in bean *(Phaseolus vulgaris)* by the similar susceptibility of these forms of resistance of heat treatment, and the differing effect of heat on some examples of parasite-specific or nonhost resistance. Studies based on following features are required to understand induced biological control.

- Absence of toxic effects of the inducing agents on the pathogens.
- Suppression of the induced resistance by a previous application of specific inhibitors, such as actinomycin D, which affect gene expression of the plant.
- Necessity of a time interval between application of the inducer and the onset of protection in the plant.
- Absence of a typical dose-response correlation known for toxic compounds.
- Specificity of protection.
- Local as well as systemic protection.
- Dependence on the plants genotype causing significant differences in level and type of protection in different cultivars.

EFFECT OF DIFFERENT FACTORS ON BIOLOGICAL CONTROL INDUCED RESISTANCE

Phenotypically, biocontrol agent induced systemic resistance and pathogen induced SAR are similar in that both mechanisms develop as a result of the interaction of plant with a microorganisms and the resulting enhanced defensive capacity is expressed both locally and sysemically against a broad spectrum of attacking organisms. To determine whether biocontrol agent induced resistance is not only phenotypically but also mechanistically similar to pathogen induced SAR, induced plants can be analyzed for

the presence of specific PRs and induction of resistance can be compared in untransformed and Nah-G transformed plants. Several ways exist for inducing resistance in plants. Among them are: inoculation with pathogen, avirulent races or nonpathogenic strains, inactivated pathogens, nonpathogens, microbial metabolites, i.e. biogenic elicitors, chemical elicitors signaling resistance. All these factors are being worked out by various workers in one form or other and being explained as induced resistance in the category of general mechanism of biological disease control. Below are explained such examples for inducing ressitance against phytopathogens, a means of biological control.

Pathogenic Organisms

Development of resistance of diseases in plants following infection has been known for over 60 year. In order to achieve successful protection, plants must recover from initial infection or must be infected at a site that does not normally become diseased. For example, immunization against blue mold intobacco can be achieved by stem injection with live sporangiospores of the causal organism of blue mold, *Peronospora tabacina* (Tuzun and Kuc, 1985a). The site of injection appears to be important since only delivery of spores into the tissue external to the xylem induces systemic resistance without stunting. In a similar way, protection can be achieved in tobacco varieties with the N gene for resistance to tobacco mosaic virus (TMV), in which the virus does not become systemic, by inoculation of two or three bottom leaves with TMV (Ye *et al.*, 1989). More interestingly, both of these pathogens induce resistance against either pathogen equally well, which may indicate activation of multiple mechanisms once the state of resistance is achieved.

The systemic protection of tobacco against blue mold is somehow unique since it was first reported on systemically stem infected and stunted field grown tobacco in Australia. Extensive field tests conducted over a 3 year period in Kentucky and Puerto Rico utilizing a modified technique (which employs injection of a sponagiospore suspension of *P. tabacina* into stem tissue external to the xylem) further indicated that tobacco plants can be protected against blue mold under vaious field conditions. These tests indicated that immunized plants had reduced lesion number and size compared to then ontreated obtained by treatment with metalaxyl. Furthermore, even in the absence of disease, immunized plants grew more vigorously and yields were increased upto 20%, compared to controls. Further field experiments were conducted in Mexico for three growing season to test the effectiveness of immunization against metalaxyl tolerant strains of *P. tabacina* (Tuzun *et al.*, 1992). Highly significant reductions in the number and size of blue mold lesions were observed on plants injection with *P. tabacina,* compared to noninjected controls, reduced blue mold onthe foliage were observed in heavily infected commerical fields indicating the natural occurrence of immunization against blue mold (Tuzun *et al.*, 1992). Tolerance to immunization was not evident, although conditions for its development were very favorable. In field compared to plants derived via tissue culture from immunized parents were also protected against blue mold compared to plant derived from control parents. Cucurbits have been utilized as model system to establish many aspects of plants immunization, including applicability of the phenomenon to the real world. Cucumbers can be protected in the field by application of biological as well as chemical inducers (Doubrava *et al.*, 1989).

These studies provide evidence that immunization of plants with biotic or abiotic

inducers effectively controls disease in the field. Utilization of pathogenic organisms in the field, however, may create problems if handled carelessly. Culture filtrates of pathogenic organisms may provide a safer alternative, and several studies have indicated induction of resistance in many crop species by microbial metabolites (Doke *et al.* 1987; Kopp *et al.* 1989; Maiss 1987; Ozeretskovskaya *et al.* 1988). Avirulent, hypoviruient and/or attenuated strains of pathogenic organisms (Kroon *et al.* 1991; Martyn *et al.* 1991; Sneh *et al.* 1989) as well as L-forms of pathogenic bacteria (Amijee *et al.* 1992) may provide additional alternatives. Capbage plants were successfully protected against the black rot pathogen, *Xanthomonas campestris pv.campestris* (XCC), under field conditions by prior application of attenuated stains of XCC or an isolate of *Xanthomonas campestris pv. malvacearum,* nonpathogenic on cabbage. In these experiments, conducted at several locations over two years, inducing bacteria were introduced into natural openings of leaves utilizing an organosilicone surfactant (Silwet) prior to transplanting and three weeks prior to pathogen challenge. Utilization of silwet to introduce organisms into leaf tissue may have a large-scale practical application by eliminating the need for injection.

Nonpathogenic Organisms

Non-pathogenic organisms that have been utilized by several research groups to induce resistance include suspensions and/or culture filtrates of saprophytic bacteria (Schmidt 1988) such as *Bacillus subtilis* (Mais 1987), *B. thuringensis* (Roveratti *et al.* 1989), *B. pumulis* and Erwinia herbicola (Reiss *et al.* 1988), and saprophytic fungi (Gregersen and Smedegaard 1989). There are also several reports that suggest induction of resistance by mycorrhiza against fungi (Rosendahl 1985), bacteria (Garcia-Garrido and Ocampo 1988) and nematodes (Carling *et al.* 1989). Although most of these studies are conducted in controlled environments, spraying plants with *B. subtilis* effectively controlled powdery mildew on barley under field conditions.

Applications of inducing agents to leaf surfaces makes the inducing agents more susceptible to stress conditions such as UV irradiation, rain washing, and temperature fluctuations. Application of good root, colonizers to seed or soil may protect inducing agents from some of these negative effects. Recently, rhizosphere bacteria, and fungi have effectively induced resistance in plants while providing other beneficial effects to plants. Meera *et al.* 1994; Free-living root and soil bacteria have been studied for the past century as possible inoculants for enhancing crop productivity. Utilization of natural microbial strains as inducers of plants defensive responses may increase the chance of their applicability and offer a practical way to deliver plant immunization.

Plant Growth-Promoting Rhizobacteria (PGPR)

Beneficial effects of PGPR that have been documented by many research groups can be summarized as: (1) direct plant growth promotion (Kapulnik 1991; Schroth and Becker, 1990), (2) biological disease control (Bakker *et al.*, 1991; Kloepper 1991; Schroth and Becker, 1990), and (3) inducing host resistance (Kloepper *et al.* 1989). The reports summarized in these reviews include the effects of many different bacterial groups on many host plants. Plants growth-promoting fungi (PGPF), however, have been described more recently from the rhizosphere of turf grass and such fungi also appear to induce systemic resistance against antrachnose disease caused by *Collectotrichum orbiculare* in cucumber plants. Although it was suggested previously (Voisard *et al.* 1989), direct pathological evidence

for the induction of systemic resistance by PGPR was first published for three plant-pathogen systems in 1991. In a carnation system applications of *Pseudomonas* sp. strain WCS417 to rockwool cubes resulted in protection from wilt caused by *Fusarium oxysporum f sp. dianthi* (Van Peer *et al.* 1991). The pathogen was spatially separated from the PGPR strain by inoculating into stems one week after PGPR application, and separation was confirmed by the failure to isolate WCS417 from stems. In a bean system, seed treatment with a *P. fluorescens* PGPR strain led to reductions in the numbers of foliar lesions caused by subsequent inoculations of P. *syringae pv. phaseolicola* (Alstrom 1991). In another report with cucumber, 94 known PGPR strains were examined for ability to control C. *orbiculare* (Wei *et al.* 1991). Six PGPR strains applied as seed treatments consistently resulted in significant reductions in anthracnose lesion diameters and lesion numbers when the pathogen was applied 21 days after planting. In a subsequent study with the 6 inducing PGPR, none of the inducing strains was recovered trom leaf petioles, confirming the spatial separation of pathogen and PGPR, These reports with carnation, bean and cucumber demonstrate that saprophytic root-associated bacteria may act as agents of induced systemic resistance, and hence, they serve to expand the potential mechanisms by which PGPR may exert biological disease control.

Protection achieved with two of the inducing PGPR strains used by Wei *el al.* (1991) on cucumber. applied as seed treatments, significantly reduced mean diameter of lesions induced by foliar-applied C. *orbicula,* PGPR-mediated protection against cucumber mosaic virus (CMV) is affected at the viral inoculation site. One PGPR strain significantly protected against CMV that was mechanically inoculated onto cotyledons (Liu *et al.* 1992). Protection was evident as prevention of symptom development on PGPR induced plants, which differs from protection reported against CMV for classical induced systemic resistance. With classical induced resistance, CMV symptoms were delayed but not prevented, With the PGPR system, both strains delayed, but did not stop, symptom development when CMV was inoculated onto the first, second, or third leaves, which is equivalent to results with classical induced resistance. The same two PGPR strains induced protection of cucumber against *Pseudomonas syringae pv. lachrymans* as seen by a significant reduction in mean lesion number and lesion size compared to noninduced controls (Liu *et al.* 1993a).

Preliminary studies with *Fusarium* wilt demonstrate that one PGPR strain reduced the rate of symptom development and plant death (Liu *et al.* 1993b). With *Fusarium,* a split root system was used to ensure spatial separation of PGPR and the pathogen. PGPR were applied to one-half of the roots after splitting, and *Fusarium* was incorporated into the soil in which the other half of the roots were growing. While this system demonstrated the potential to use PGPR-mediated induced resistance for protection from a soilborne vascular wilt pathogen, it is fundamentally different from the other PGPR systems, which use seed treatments. PGPR applied as seed treatments may induce systemic resistance earlier in the plant's life, and hence, more work is needed to compare the biochemical responses of plants induced by seed and root treatments with PGPR.

Several studies have indicated that specific PGPR may stimulate the production. of biochemical compounds associated with host defense. Van Peer and his colleagues (1991) observed increased accumulation of phytoalexins in' carnation plants treated with PGPR (isolate WCS417) following pathogen ejaculation. In a bean system, Hynes &

Lazarovits (1989) found that levels of a vacoulation increased in leaves following seed treatment with PGPR strains. Plants root colonization by PGPR was associated with increased peroxidase activity and enhanced lignification of stems or leaves in bean (Anderson and Guerra, 1985) and wheat (Frommel *el al.* 1991). Inoculation of bean root with a *P pulida* parR strain led to a increased. abundance of mRNA encoding PRIa protein in leaves. These reports clearly demonstrate that particular bacteria inoculated onto seeds or roots may elicit systemic physiological changes in plants.

Early investigations with PGPR-mediated induced resistance in cucumbers suggested that the biochemical response of the plant may depend on the inducing PGPR strain. Some inducing PGPR were associated with enhanced peroxidase activity similar to that observed with classical induced controls: Some, but not all, inducing PGPR strains were associated with enhanced mRNA encoding acidic chitinases. It will be necessary to conduct further biochemical investigations of how PGPR-mediated and classical induced resistance affect host defense-related compounds.

Critical Gaps in Technology

In the soil ecosystem, numerous interrelationships between microbial communities, host plant, and pathogen take place. The complexity of these interrelationships, and to a greater extent our lack of knowledge of their structure, prevents development of functional and effective management system. The management of the interrelationships between the biological elements of the agro ecosystem with those of the crop production system as they relate to root health and disease management is today's requirement. Management practices that increase overall (or segments of) naturally occurring microbial communities that are responsible for improving root health would be an alternative approach to biological control systems. Effective management of microbial communities could lead to stability of soil ecosystems and improved root health. . Management of microbial communities would be adaptable to many of the newly developed crop production systems. It would definitely be an important approach to integrated pest and disease management in cropping systems where organic matter accumulation is favored and where plant diversity is promoted, for example: low input, nontill, organic, multiple-cropping, and intercropping systems. Such an approach could have a strong impact in subsistence agriculture where these attributes are common.

Liquid fermentation technology

The rapid expansion of fermentable biotechnology over the past three decades has a greater awareness of the usefulness of antagonistic fungi for the production of large amount of acids, antibiotics, enzymes, etc from expensive and/or waste ingredients.

Genetic improvement

While many naturally occurring biocontrol agents have been found, it is still possible to screen for more efficient isolates. There is great scope for improving the efficiency of biocontrol agents in the form growth and insensitiveness to commonly used fungicides.

Biological seed treatment

The problem of delivering the antagonist remains to be the greatest obstacle in commercializing the novel practice of biological control, despite the fact that the last few

decades have witnessed significant developments in biological control of soil-borne plant pathogens. Biological seed treatment has tremendous potential to make biological control a great success especially for seed and seedling diseases in vegetable, fruit, forest and other plantation crop nurseries. Seed companies want effective biological seed treatments. There are particularly interests in broad-spectrum seed protect ants to replace captan or thiram. Moreover, restrictions to several countries on the application of these chemicals and the disposal of unused treated seeds make use of these materials difficult. For biological seed treatments to replace the more standard chemicals, they must consistently effective against range pathogens.

POTENTIAL AREAS OF RESEARCH

The antagonistic microorganisms are known to exhibit specificity in action against specific plant pathogen. Conditions often exist in agricultural fields where the crop may be exposed to several plant pathogens over time. Unfortunately, biocontrol agents are generally developed to control only one pathogen due to the difficulties inherent in developing and testing organisms effective against multiple pathogens. Strategies, therefore, need to be developed for application of multiple organisms and separate niches maintained, enabling control of multiple pathogens. By combining specialized biocontrol agents that incorporate different mechanisms of biocontrol for multiple pathogens, a potentially more stable and effective control may be achieved. Practical approaches have to be developed whereby the appropriate antagonistic microorganisms individually or in combination with other microbes can be formulated for enhanced biocontrol of plant pathogens.

1. Use of a single species or strain of microorganism, with proven biological control activity, for the control of a specific target pest or disease is presently the most popular strategy for increasing biological diversity in the soil on a commercial basis Diverse mechanisms of action have been reported including: antibiosis, repellents, toxins, and induced resistance. Till now, the indirect effect mechanism of action for eg. use of antagonist in inducing host resistance associated with biological control agents is poorly understood. Indirect mechanism (competition for nutrients) and their impact also may be directly associated with shifts in microbial communities due to invasion of rhizosphere niches and needs a special attention.

2. Biological control activities of complex mixtures of unknown species and strains of microorganisms present in organic amendments and composted organic material has not been studied in detail even though amendments have been repeatedly shown to reduce soil borne diseases. Difficulty in monitoring the active components of the microbial community in these complex substrates has limited progress in the development of biologically activated amendments for commercial use as a plant protection system. The antagonistic potential responsible for suppressive activity in such amendments is most likely not driven by the activity of one species, but the action of a community of microorganisms from diverse taxa with different mechanisms of action. The type and degree of biological control activity produced is also determined by composition, maturity, and form of amendments.

3. The role of crop cultivars playing influencing microbial community structure is for the most part unknown. The vast number of studies dealing with cultivar specific changes in soil microorganisms usually relates to shifts in resistance to any pathogen.

The presence of fungal and or bacterial endophytes in the root tissue has recently been shown to increase plant resistance to pathogens and in some cases induce systemic forms of resistance. The importance of the endophyte community structures for root health is still a neglected area, but it is a field of research that needs attention.

4. The fact that crop rotation is the most effective short- and long-term plant protection measure for control of many soil borne pests and diseases is indisputable. In organic and conventional cropping systems, crop rotation is the major instrument used to reduce pests and diseases. Advance in methodology to study microorganisms in soil has helped demonstrate the large degree of spatial and functional interrelationships between pathogenic and nonpathogenic microorganisms within the root system, and the ultimate effects of these interactions on root health. Research directed at the measurement of rhizosphere community structure influenced by cropping system is a relatively new field and has a vast scope in understanding the mechanism.

5. Genetic analysis of rhizosphere colonization genes and traits need to be understood. Little is known about the expression of biocontrol agents for effective colonization of the subterranean portions of plants. This is due to the genetic complexity of the colonization phenotype and in part, to the inadequate methodologies for genetic analysis of rhizosphere colonization, however studies on the distribution and survival of known antagonists in the root system have been studied.

As stated above, increasing diversity in an individual crop through the introduction of a biological control agent should create new interactions within the endemic microbial community. The number of new interactions created may be equal to or greater than the number of introduced microorganisms, if each new organism occupies a separate niche. The establishment of competition for ecological niches between the antagonistic microorganism and the disease agent is a major mechanism of action often associated with unnoticed approaches to biological control. In general, heterogeneity plantings of crops should stimulate heterogeneous niches in the rhizosphere environment.

The interaction between pant pathogens is not only affected by the density or microbial spectrum of the community, but also by the function or activity of the individual components in that community. Our lack of knowledge of how these interrelationships work and how they are driven along with the fact that a vast number of soil microbial species are still unknown, confirms the need for more research. Some progress has been made in identifying highly effective antagonists in rhizosphere communities. We feel that more stress should be placed on a better understanding of microorganisms in cropping systems. With more knowledge of community structure, ecologically sensitive agricultural production systems could be developed that favor higher levels of biological diversity and self-regulation mechanisms which lead to improved root health. Microbial diversity in the rhizosphere is closely related to plant diversity, especially with regards to qualitative and quantitative shifts in populations of pathogens, nonpathogens and antagonists. Three major areas emerge holding practical utility: (a) manipulation of antagonist environment, (b) development of antagonistic mixtures, (c) manipulation of antagonists to increase their ecological fitness and biocontrol function. The final goal must be to manage specific components of an agro-ecosystem through a form of biological system management-to increase diversity to its highest level of fitness as it relates to root health.

TRICHODERMA USED AGAINST PATHOGENS IN DIFFERENT ENVIRONMENTS IN SOIL

The introduction of fields as seed coatings and in granular form broadcasting infurrows application. *Trichoderma* spp. for biological control of soil borne pathogens has been introduced as seed coating and as granule formulated for broadcast or infurrow application or for planting soil amendments. Currently, trials are being carried out on the effect of cover crops whose roots are colonized by rhizosphere-competent, *Trichoderma* strains. Granules for mixing into soil are intended to introduce *Trichoderma* into the microflora and increase the disease suppressivpeness of the soil, and such treatment usually takes pace at the time the crop is planted as an infurrow application. Tomato seedlings grown in *Trichoderma* amended potting soil can better resist disease even when transplanted into fields known to have a history of *Fusarium* crown and root rot (Datnoff *et al.*, 1993).

The intention of applying *Trichoderma* to cover crops or as seed treatments is to establish the agent locally in the rhizosphere. Rye grain or eye grass cover crops are sown in autumn and colonized by rhizosphere competent *Trichoderma* isolates following seed or infurrow treatments. The following spring these cover crops are killed shortly before the target crop is sown and their colonized roots provide a reestablished source of inoculum for the new crop. This treatment has resulted in enhanced root growth and increased crop yields, microflora. There are several advantages in applying *Trichoderma* as a seed treatment. Large amounts of seed can be treated simultaneously and efficiently, and this procedure can be included in processing by the seed company. Thus, furthermore, allowing the agent directly on the target site means that a relatively small amount of the biocontrol agent is needed. The efficacy of biological treatments for seed protection may depend on the relative rates with which the antagonist and pathogen colonize the seed. *P ultimum* is able to germinate as soon as 2 h after stimulation with rot exudates, and colonizes the seed very rapidly after planting (Harman and Nelson, 1994). It is necessary to somehow give the biocontrol agent on the seed a head starts, without at the same time stimulating the pathogen. Double coating is a treatment that may solve this problem (Taylor *et al.*, 1991). The antagonist is applied in a slurry in 10% pelgel. Subsequently, AgroLig is applied as a second, thin, uninterrupted coat. When this seed takes up water in the soil, the added nutrients dissolve and start to lead from the seed into a closed time to germinate and start growing before the pathogen is stimulated by the seed exudates. The disadvantage of the slow germination rate of *Trichoderma spp.* compared to some seed pathogens can thus be overcome. This has demonstrated the importance of designing the seed protection formulation specifically for the seed type and disease problem in question formulation (Harman and Taylor 1990, Harman *et al.*, 1981, 1989, Nelson *et al.*, 1988).

Integrated biological-chemical seed treatment treatments may provide better results than treatment with either the chemical or biological agent alone. The possible explanation can be that chemical protectant can provide the best short-term protection of seed or seedling itself. A rhizosphere-competent bio-protectant, on the other hand, can colonize the entire root system and provide a degree of seasonlong protection unattainable through acceptable levels of chemical treatment. In a clay loam soil treated with 4-12 ug triadimefon per gram soil, the population density of antagonist *Trichoderma harzianum*, which is

insensitive to the fungicide, was increased in the rhizosphere around the root it (1-4 cm) of watermelon. Application of 4 ug triadimefon increased the rhizosphere competence index of *T. harzianum* and its population density at the 4-8 cm and 1-14 cm root segments, compared to the untreated control. The increased proportion of the population of *T. harzianum* in rhizosphere soil was higher at the inoculum dose of $1X10^3$ cfu/g soil that at $1X1^6$ cfu/g soil. Tha antagonist populations at both inoculum doses with the triadimefon treatment were higher than that of the untreated control.

PHYLLOSPHERE

The surfaces of flowers and leaves are much more hostile habitats for microorganisms than soil due to low nutrient availability, extreme temperatures, drought and intense radiation. It may be difficult for an antagonist to establish itself in this environment, however, if an aggressive biocontrol agent is able to establish itself before the arrival of the pathogen, it may be able to prevent disease. Formulations designed for phylloshere application usually inclùde additives to facilitate the agents colonization (e.g. nutrients and stickers). As mentioned above, care must be taken not to use additives that could stimulate the pathogen under the nutrient poor conditions of the phylloshere. *Botrytis cinerea* is one of the most serious pathogens on grape vines. Atleast under conditions of low disease incidence, *T. harzianum* has been successfully used against this pathogen in Italy (Bisiach *et al.*, 1985) Gullino, 1992) (Gullino and Garibaldi, 1983), France (Dubos and Bulit, 1981) (Dubos *et al.*, 1978, Israel) (Elad, 1994), and the United States (Harman *et al.*, 1996). The time of treatment is important for control. Most effective protection is obtained by treatments extending from the time flowering to three weeks before harvest but partial protection is also obtained by only spraying during the flowering period (Dubos *et al.*, 1982). The best control however, is obtained in an integrated program using *Trichoderma* together with a reduced dosage of fungicides (Gullino, 1992 Harman *et al.*, 1996).

Another disease caused by *B. cinerea* that can be controlled by *T. harzianum* is dry eye rot on apple. Under humid conditions B. cinerea attacks apple flowers, grows into the sepals, and later causes dry eye rot (Tronsmo and Raa, 1977). Natural infection by B. cinerea has been reduced significantly by using cold tolerant isolates of *T. harzianum* (Tronsmo, 1986a Tronsmo and Ystaas, 1980). Even better control has been obtained in an integrated control program where a fungicide resistant mutant of *T. harzianum* was used together with a reduced amount of the fungicide, vinclozolin (Tronsmo, 1989). Interestingly, this isolate showed better control than the parent strain, even without the fungicide (Transmo, 1991). Improved biocontrol abilities of fungicide resistant *Trichoderma* isolates have also been observed in other biocontrol trials (Papavizas and Lewis, 1983 Papavizas *et al.*, 1982). Improved abilities have been found in T. harzianum against tomato damping off by using with captaf and carnation wilt with carbendazim (Sharma, 2000, Sharma, 2002).

Different approaches to disease control have been evaluated in order to reduce the incidence of diseases caused by various soil borne pathogens in several crops. Cultural practice and application of fungicides are currently practiced in many areas. Extensive use of plant protection chemicals and some times their indiscriminate use have led to serious social and environmental repercussions. The poisoning of livestock, fish, wild life and their beneficial organisms has been due to increase use of these chemicals. There

has also been disturbing increase in human poisoning, particularly in developing countries, where safe handling and application of plant protection chemicals are not always feasible due to several socioeconomic factors. Moreover, some of the chemicals are very expensive and can not be afforded by Indian farmers. In addition, the chemicals are required to be applied at intervals and in large quantities to treat the soil, results in increased cost of cultivation. Thus, increasing awareness of environmental and socioeconomic problems by the use of fungicides have encouraged the search for more biologically sound alternatives. The implementation of *Trichoderma* spp. in integrated pest management (IPM) can be achieved using a soil treatment which combines reduced amount of biocides fungicides and the *Trichoderma* preparation. Biocontrol activity can be increased by combining two or more types of biocontrol agents. Moreover, the construction of a genetically modified *Trichoderma* can lead to the improvement of certain traits which are absent or not highly expressed in the native microorganism isolated from its natural habitat. As biocontrol is an integral art part of the IPM philosophy, judicious use of *Trichoderma* against soil borne pathogens, when demonstrated to be consistently effective, practical and economic, can serve as a model for the introduction and implementation of other biocontrol means into IPM.

Recently, there has been a large upsurge in the interest in biological plant disease control mainly in hostcultural cropo reflecting increasing environmental concern over pesticide use (Whipps 1993, 1997). This interest has been further stimulated by the fungicide resistance problem of some pathogens and the missing links in management of soil borne pathogens. The concept of biological control developed as early as in 1993s which became popular in the last decades is a tremendous break through in the research efforts on biological control of plant diseases of a variety of crops are being studied for the management through soil and seed treatment. The biological seed treatment can also be effectively combined with compatible chemical pesticide at lower doses since many of the antagonists are found to be insensitive to these pesticides to a certain concentration (Sharma, 2001).

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5

BIOMANAGEMENT : BOTANICAL PESTICIDES

The constant use of fungitoxic chemicals adds to the environmental pollution. Consequently, efforts are under way to find alternatives to chemical fungicides. Studies conducted on the use of plant extracts have opened a new avenue for the control of plant diseases. Besides being safe and non-phytotoxic, the plant extracts are known to be effective against various plant pathogens (Misra and Dixit, 1977a; Misra and Dixit, 1979;Tiwari *et al*, 1988).

Bioactive products of plants being less persistent in environment and are safe for mammals and other non-target organisms. Botanical pesticides are readily available in many places, often cheaper than their systemic counterparts and their crude extracts are easy to prepare even by farmers. These slow down the development of resistance or resurgence in pests. The benefits of natural pesticides have aroused interest in protection of crop plants.

The important role that plants may play as a source of natural chemicals and their importance in controlling different agricultural pests is well documented. Many workers have reported antifungal activity of plant extracts, volatile materials or oils against different plant pathogenic fungi and recent studies on the subject emphasized the importance of natural chemicals as an alternative to synthetic pesticides in any future strategy for pest control.

PLANTS AS A SOURCE OF PESTICIDE

Plants are richest source of bioactive organic chemicals. More than 400.000 chemicals have already been identified. Of these 10, 000 are secondary metabolites whose major role with plant is reportedly defensive especially against insect pests because the overall pressure of insects on plants is more than any other herbivore. Large number of defensive chemicals belonging to various chemical categories (terpenoids, alkaloids, glycosides,

phenols, polyacetylene etc.) has already been identified. These chemicals have diverse biological effects on variety of pests.

BOTANICALS AGAINST DISEASES OF VEGETABLES

Management of commercial vegetables in ways to minimize the risk of diseases is important to sustain success over the long term. Commercial vegetable growers should focus on disease prevention rather than curing plants of diseases, because in general the tools are not available to cure plants of diseases. The strategy should be to use cultural practices that keep the pathogen populations low, that slow spread, that improve the plant's resistance or tolerance to diseases where possible [many production techniques required to achieve desired market standards of quality and acceptable yields actually increase susceptibility to certain diseases], and take steps to minimize disease-favorable environments. Chemicals should be viewed as only one part of a total disease prevention program, albeit a very important part, of most modern production approaches. A carefully managed vegetable operation combines cultural practices and selected chemical treatments to obtain prevention and achieve maximum disease control, although diseases can be managed with cultural approaches if adequate inputs are used. It is especially important in commercial vegetables to stop epidemics early in the season, because once most infectious diseases are well established and developing rapidly many are nearly impossible to control under ideal weather for the disease. Essential oils and neem seed limonoids identified as potential botanical pesticides - against rice pathogens and spice & vegetable diseases. Pure triterpenoids from neem oil showed excellent antifungal activity against *Dreschlera oryzae, F. oxiysporum* and *A. tenuis*. An IGR from *Catharanthus roseus* developed and field-tested against *Myzus persicae, S. litura* and *H. armig*era. Studies on insecticidal and antifeedant activity are underway in the plants viz., *Clerodendron inerme, C. siratum, C. phlomidis, Cymbopogan, Aglaia elaeagnoidea, Chukrasia tabularis* etc.

Dubey and Dwivedi (1991) found *Allium cepa* inhibiting the mycelial growth and spore germination of *Fusarium oxysporum f. sp. niveum* at a higher dose. Further, the use of this extract for seed soaking significantly controlled seedling wilt of watermelon. Similarly, antifungal activity of *Allium cepa* was observed by Misra and Dixit (1977b) against 11 pathogenic fungi.

Ethanol extracts of 10 plant species (*Allium cepa, Allium sativum, Azadirachta indica, Calotropis procera, Datura stramonium, Ocimum sanctum, Polyalthia longifolia, Tagetes erecta, Vinca rosea and Withania somnifera*) showed fungitoxic properties against five pathogenic fungi, *Alternaria brassicola* (Leaf spot of mustard), *Colletotrichum capsici* (fruit rot of chilli), *Fusarium oxysporum* (wilt of chilli), *Rhizoctonia solani* (collar rot of okra) and *Sclerotinia sclerotiorum* (stem rot of mustard) when tested under laboratory conditions at two concentrations. Higher dose of few plant extracts was relatively more efficient (Shivpuri *et al.*, 1997).

Yadav and Jat (2004) studied the effect of oils and plant extracts on post-harvest fruit rots in Anola caused by *Aspergillus niger*. They found that pre-inoculation of plant extracts reduce the disease severity, however extract of *Azadirachta indica* was significantly better over extract of *Vinca rosea* but at par with extract of *Curcuma longa* & *Zingiber officinale* in controlling the rot. In post-inoculation treatments *Azadirachta indica* was found significantly superior over all the treatments except *Curcuma longa* to control the Aspergillus fruit rot.

Leaves of eleven plants viz. *Aloe vera, Asparagus officinalis, Calotropis procera, Catharanthus roseus, Cassia occidentalis, Datura innoxia, Lantana camara, Opuntia* sp., *Parthenium officinalis, Ricinus communis* & *Thuja occidentalis* were evaluated for their antifungal properties against seed borne fungi in *Dalbergia sissoo*.The extracts of *Cassia occidentalis, Lantana camara, Opuntia* sp. & *Thuja occidentalis* were found best for the significant control of seed borne infection with respect to their control (Gupta and Singh, 2004).

Singh *et al.* (2003) found that Sadabahar and garlic extracts inhibited 83.8 and 82.2% growth of pathogens in the management of *Sclerotinia* stem rot of ajowan.

Tiwari *et al.* 1988 found leaf extract of *Ocimum sanctum* quite effective in reducing the growth of *Rhizoctonia solani* in vitro & in vivo.

Crude extracts from plant materials have been found to significantly inhibit mycelial growth of many pathogenic fungi (Shetty *et al.* 1989; Owolade and Osikanlu, 1999). The efficacy of aqueous extracts from the leaves of *Carica papaya, Tithonia diversifo;ia* and *Acalypha ciliata* as potential biofungicide against *Colletotrichum capsici* was evaluated in vitro and in vivo. Crude extracts of the three plants inhibited the mycelial growth of *C. capsici* on potato dextrose agar in laboratory. Extracts of *A. ciliata* and *C. papaya* totally inhibited mycelial growth at concentration of 80 and 100% of each plant crude extract. Field sprays of these crude extracts at 20% concentration significantly (P=0.05) reduced disease incidence and severity and their performances were comparable to benlate. The aqueous extract of of the three plants used in this study contained varying amount of mineral associated with fungitoxicity (Owolade *et al.*, 2003).

In vitro evaluation of different botanicals indicated that water hyacinth; neem cake and neem leaves resulted in significant inhibition of *D. microsporus*. When these botanicals were incorporated in the compost, water hyacinth resulted in drastic reduction in the incidence of false truffle, irrespective of type of inoculum and significant increase in the yield of both *A. bisporus* and *A. bitorquis* (Sharma and Jharial, 2000).

Grewal and Grewal (1988) reported differential fungicidal property of leaf extracts of *Azadirachta indica, Chrysanthemum indicum* and *Tagetes erecta* against various weed molds of mushroom. Sarkar et al. (1988) advocated the use of *Casurina* leaves and water hyacinth for reducing the incidence of weed fungi occurring in Pleurotus beds, which also increased the yield of mushroom. Sharma and Jandaik (1994) also recorded inhibition of some weed fungi namely, *Myceliophthora lutea, Papulaspora byssina, Chaetomium globossum* and *Trichoderma viride* encountered during the cultivation of whole button mushroom, by the use of neem leaves.

Tripathi *et al.* (1985) reported a strong volatile fungitoxicity against betelvine pathogen, *Alternaria* sp., *C. capsici* and *Sclerotium rolfsii* using extracts from *Ocimum gratissimum*. Owolade and Osikanlu (1999) and Owolade *et al.* (2000) observed significant control of *C. capsici* on cowpea and *Fusarium moniliforme* on maize using the crude extracts from the leaves of *O. gratissimum*.

Jacob and Sivaprakashan (1994) found the leaf extracts of *Eucalyptus terticornis* to give best control of *Pythium aphanidermatum* causing damping off in brinjal. Narayan Bhat and Sivaprakashan (1994) tested cold and hot water leaf extracts of 25 crop plants and 30 forest trees in vitro. The cold-water extract of *Polyalthia longifolia* exhibited 56.6 per

cent inhibition of mycelial growth, whereas hot water extract of *E. microtheca* resulted in 90 per cent inhibition. Leaf extracts of some plants were more effective in cold water, whereas in some cases hot water was more effective.

Muthulaxmi and Seetharaman (1994) tested leaf extracts of five plants, *A. marmelos, P. Juliflora, I. cornea, O. sanctum* and *Bougainvillea spectabilis* against *A. tenuis* causing fruit rot of chilli (*Capsicum annum*). In the in vitro studies of poisoned food technique, *A. marmelos* exhibited maximum inhibition of mycelial growth (87.56 %) followed by *P. juliflora* (83.72 %) and *I. cornea* (70.12 %). In pot studies both pre inoculation and post inoculation spray of leaf extracts significantly reduced fruit rot. *A. marmelos* leaf extract (10 %) spray had least fruit rot incidence (21.70 and 13.48 per cent respectively) followed by *P. juliflora* leaf extract (26.8 and 18.77 per cent) as compared to control (84.62 and 84.62 per cent) under pre and post inoculation spray respectively. The yield was maximum (78 g/pot) in case of *A. marmelos* leaf extract followed by *P. juliflora* leaf extract (72g) as compared to control (55g).

Cucumber: Doubrava *et al.* (1988) induced systemic resistance to anthracnose (*Colletotrichum lagenarium*) in cucumber by using extracts of spinach and rhubarb leaves.

Garlic clove juice was effective in controlling Fusarium wilt of watermelon (El-shami *et al.*, 1986).

Tomato seeds treated with aqueous extract of garlic (30g/100ml water) for 12 hours controlled seed borne *Xanthomonas campestris pv. vesicatoria* and reduced the severity of the disease (Mangamma and Sreeramulu, 1991).

Melon: Bankole and Adebanjo (1995) effectively controlled seed borne fungi of melon by seed treatment with leaf extract of *Cymbopogon citratus.*

Vegetable oil sprays: Cooking and salad oils are more readily available than most other oils and are probably less disruptive to the environment. Vegetable oils are biodegradable and shouldn't cause any long-term problems in the garden. Emulsified vegetable oil sprays of sunflower, olive, canola, peanut, soybean, corn, grapeseed, or safflower can control powdery mildew on apple trees, roses, and possibly other plants, and cottonseed oil has considerable protective value against powdery mildew. However, emulsified vegetable oil can leave a greasy film on leaves, which you might find objectionable. Check for plant damage before general use, and be especially careful of blooms.

Herbal oil sprays: Essential oils such as those made from basil, fenugreek, cumin, mint, clove, and eucalyptus may be effective against a number of fungal pathogens. For instance, solutions of cumin or clove oil completely inhibit sugarcane rot, and basil oil can inhibit growth of soilborne pathogens. A commercial formulation of mint oil (Funga-Stop) is available to help control soilborne pathogens. However, these essential oils need to be researched further before they become prevalent in horticulture.

Neem oil: Neem is derived from the neem tree, a native of Myanmar (the former Burma) and India. Extracts of neem seeds are used as insecticides; they kill insects as they molt or hatch. Recently, fungicides made with neem oil have become available commercially. Neem oil appears to have better fungicidal properties than many of the oils described above, perhaps because neem contains sulfur compounds, which have their own fungicidal properties, as well as other natural pesticides. A neem-oil formulation called

Trilogy has been approved by the EPA for use on foods, while Rose Defense and Triact (for control of powdery mildew, rust, black spot, Botrytis, downy mildew, and other common diseases) are designed for use on ornamentals.

Plant preparations have been used for centuries in medicine and pest control. For example, opium from the opium poppy was one of the first pain killers. Farmers in India use neem leaves to protect their stored grain from insects. Herbs and spices, such as basil and clove, have been used by many cultures to protect food from spoilage, as both have antimicrobial properties.

Milsana: The German corporation BASF capitalized on this concept in 1993 by screening a large number of plant extracts for their fungicidal properties. The most promising result was a dried extract of the giant knotweed, *Reynoutria sachalinensis*, which is now sold as a fungicide under the brandname Milsana. Knotweed extract has only recently become commercially available in the United States, so feedback from U.S. gardeners is sparse. Italian researchers have found that Milsana reduced powdery mildew infection on cucumber by 50 percent, and similar sprays protected roses, but these were less effective than oils, soaps, and other non-toxic products. Repeated sprays of Milsana induced a greener and glossier coloration of the leaves, but they became brittle to the touch.

Garlic: Sprays made from aqueous garlic extracts have antibiotic and antifungal properties and will suppress a number of plant diseases, including powdery mildew on cucumbers and, to some extent, black spot on roses. Activity may be due to sulphur-containing compounds such as ajoene or allicin.

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6

RESISTANT VARIETIES

One of the most important components in any Organic Farming Programme and Integrated Pest Management is the selection and planting of cultivars that are resistant to pathogens. The term resistance usually describes the plant host's ability to suppress or retard the activity and progress of a pathogenic agent, which results in the absence or reduction of symptoms. However, it is important to clearly establish a common definition of the term when discussing this quality with individuals from different sectors of the agricultural industry. Growers, researchers, plant breeders, and seed sellers may have slightly different understandings of the term. In addition, the word tolerance, which has a slightly different meaning, is sometimes used interchangeably with resistance, resulting in some confusion. By definition, tolerant plants can endure severe disease without suffering significant losses in quality or yield, however, these tolerant plants do not significantly inhibit the pathogen's activity, and disease symptoms may be clearly evident. Resistant plants usually suppress the pathogen in some fashion.

Breeding for resistance to disease and insect pests has been done for almost as long as systematic plant breeding has existed. Progress has been incremental, driven by the need to prioritize and deal with those pests that caused the greatest economic loss. As resistance has been incorporated and diffused into many cultivars, then the next most pressing pest problem has been tackled. Another factor driving breeding for disease resistance has been the availability of other means of control. For example, while fungicides allow economic control of fungal pathogens, few chemical or cultural methods are available for preventing viral diseases. Genetic resistance is available for many pathogens, so breeders have incorporated these for the most important disease problems. Considerable strides have been made in developing disease and pest resistant vegetable cultivars. Still, there are many disease and insect pests that present challenges to contemporary vegetable production.

A second reason for the need for continued breeding efforts is the naturally variable, biological systems of the host and pathogen or pest. Old diseases become new problems, and new diseases arise. As disease resistance is deployed, it gets harder for a pathogen to survive, which creates selection pressure for individuals in the pathogen population to develop new ways of overcoming the resistance. Secondly, production systems may change. When cropping systems intensify, the microenvironment changes and pathogens may find new opportunities. For example, green and dry bean producers are using higher populations in the field to achieve higher yields, but greater plant densities create an environment favorable for white and gray mold. Thirdly, diseases and insects will migrate sometimes on their own, sometimes with assistance from humans moving seeds and plant parts. While preferring soybean as a host, aphid populations build up to such an extent that they migrate to nearby vegetable crops. During migration, they acquire viruses such as cucumber mosaic and alfalfa mosaic that are not normally a problem on snap bean, and spread these in snap bean fields on a large enough scale to cause economic losses. Late blight of potato and tomato provides another example. While late blight has been present in the U.S. since at least the 1830s, it has been of one mating type such that no sexual recombination occurred. Thus, the pathogen remained fairly uniform genetically, and resistances in the host remained effective. A new mating type arrived from Mexico in the 1990s, which has allowed the development of more virulent races.

TYPES OF RESISTANCE

Disease resistance can be broadly classified as vertical and horizontal resistance. A gene for gene relationship between the pathogen and host characterizes the former type of resistance. One or a couple genes with major effect usually control resistance, and the effect is large - disease is present or not. Breeders prefer to work with single genes with large effect because they are easy to screen and transfer during the breeding process. This type of resistance, however, is more likely to be overcome by the development of new virulence genes in the pathogen. Horizontal resistance has traditionally been described as controlled by few to many genes with small individual effect. Resistance is not observed as an "either -or" effect, rather a continuum of resistance is observed. Because of its more complex genetic basis, horizontal resistance is more difficult to overcome by the pathogen. It has also been more difficult for breeders to manipulate because it requires population breeding strategies and statistical techniques to determine which progenies have improved resistance.

Much of breeding for disease resistance up until present has relied on vertical resistance. The "easy" pathogens and host genetics have been characterized, and as it turns out, these have been typically been the vertical resistances. Now, we are facing the challenge of understanding the "difficult" pathogens - those for which only horizontal resistance is available.

There are methods to overcome the drawbacks of breeding for each type of resistance. For example, gene pyramiding allows one to incorporate several resistance genes into one cultivar, making it more difficult for a pathogen to overcome them all. Pyramiding is also being used successfully for resistance to rust and anthracnose in several crops. This technique would seem to have application to other diseases, such as late blight. For horizontal resistance, new molecular tools are allowing breeders to understand the underlying genetics of quantitatively inherited resistance, and allow the efficient

manipulation of those genes. The use of molecular mapping and quantitative trait locus analysis are the modem to transfer resistance from one genus to another. Research on breeding for disease resistance using the standard breeding procedures has resulted in the release of large number of varieties. Impact of vegetable research and management has resulted in development of a large number of improved varieties and wider adaptability and standardisation of their production technologies for various agro-climatic conditions has made it possible to produce vegetables in wider areas and has improved the prospects of their supply tremendously as follows.

Need to develop resistant varieties in following crops

Tomato	leaf curl virus, TMV bacterial wilt, Phytopthora blight,
Brinjal	bacterial wilt, little leaf
Okra	yellow vein mosaic
Chillies	virus and pest complex
Onion	purple blotch, Stemphylium (moth and thrips)
Cucurbits	downy mildew, powdery, CMV, fruit fly
Cole crops	Sclerotinia, Alternaria and soft rot
Peas	Powdery mildew
Beans	Septoria, mosaic virus

List of important varieties developed in different institutes have been compiled in Tables 1-6, including resistant/tolerant varieties also.

TABLE 1

Important vegetable varieties developed from IARI

Crop	Varieties	Resistant/Tolerant to
Brinjal	Pusa Bhairav	Phomopsis blight
Cabbage	Pusa Drum Head	Black leg
	Pusa Mukta	Black rot
Cauliflower	Pusa Shubhra	Black rot and Curd blight
	Pusa Snowball K-1	Black rot
Chilli	Pusa Jwala	CMV, TMV and Leaf curl
	Pusa Sadabahar	
Cow pea	Pusa Komal	Bacterial blight
Lab lab bean	Pusa Sem-2	Viral diseases
	Pusa Sem-3	
Musk melon	DMDR-2	CGMMV and Downy mildew
Okra	Pusa Sawani	YMV
	Pusa A-4	YMV
Tomato	Pusa-120	Root knot nematode
	Pusa Hybrid-2	

Division of Vegetable Science, A profile published by Head, Division of Vegetable Science, IARI, New Delhi, Jan 2005, p. 10.

TABLE 2

Vegetable varieties resistant to major diseases

Vegetable	Disease	Resistant varieties
Brinjal	Bacterial wilt	BB44, SM66, hybrid 444, Bb7, Bwr 12, Pant Samrat
Okra	Yellow vein mosaic virus	EMS8, AROH 1, BO 1, BO 2, HY 7, HY 8, Okra No 6, HOE 202, 1.5.B.4, DOH 1, DOH 2, GOH 3, GOH 4, Pusa Sawani, P7, PB 57, Sel 10
Tomato	Late blight an	A 2, KT 10, KT 15, 1.5.B.6, TBR 1, Solan Gola,
	Buckeye rot	Roma, S 12
	Bacterial wilt	BT 10, LE 79-5, BT 1
Musk melon	Downy mildew	MR 12, Hara Madhu

Peter, K.V. 1998. *Genetics & Breeding of Vegetables.* ICAR, Publication, New Delhi, pp: 309-310.

TABLE 3

Important varieties of vegetable crops

Open pollinated varieties of vegetables

Name of the crop	Important varieties
Tomato	HS-101, HS-102, HS-110, Sweet-72, Punjab Chhuhara Roma, KS-1,
Determinate	Punjab Keshri, Sel-7, Sel-32, Sel-152, Sel-12, Pusa Early Dwarf, Pusa Gaurav, CO-1, CO-3, Labonita, Sel-1-6-1-4, Hisar Lalima, Pusa Red Plum, Pusa Sel-4, Pusa Sel-8, Pusa-120, Balkan
Indeterminate	Best of All Pant Bahar, Pusa Ruby, Sel-120, Sioux, T-1, Arka Vikash, Arka Saurabh, DT-10, BT-12, Pant T-3.
Brinjal	Pusa Purple Long, PBR-128-5, PBR-61, Sel-1, Punjab Sadabahar,
Long	Neelam, PH-4, Pusa Kranti, Pant Samrat, Azad Kranti, ARU 2C, BB-26, Sel-4, Punjab Barati, KT-4, NDB-25, ARUK, Arka Sheel, Punjab Chamkela, Arka Navneet, PBR-9-1, PBR-91-2, Punjab Bahar
Round	Jamuni Gol Baigan, Pant Rituraj, H-8, KS-224, AB1, K202-9, DBR-31, DBR-8, T-3, Pusa Purple Round
Small Round	PLR-1, Aruna, DBSR-44
Brinjal Green	Arka Kushmakar, Arka Shirish, Ramnagar Ziant, Rajendra Baigan
Chilli	Andhra Jyoti (G-5), Bhagyalaxmi (G-4) K-2, K-1, Sel-1, J-218, Muslabadi, LCA 206 B, JCA 283, Phuley C-5, Bhaskar, CO-1, CO-2, MDU-1, NP-46-A, Punjab Lal, Pusa Jawala, Pant C-1,

Contd...

Name of the crop	Important varieties
	Pant C-2, JCA-154, Kalyanpur Selection, Pusa Sadabahar, X-235, Kalyanpur Red, Chamatkar, Kalyanpur Red, Aparna, G-3.
Capsicum (Bell pepper)	California Wonder, Yolo Wonder, King of North, Early Ziant, Bull Nose, Chinese Gaint, World Beater, Arka Mohini, Arka Gaurav, Arka Basant.
Okra	Pusa Sawani, Punjab No-13, Red Bhindi, CO-1, Perkins Long Green, Ghana Red, Gujrat Bhindi-1, Selection-2, EMS-8.
Water melon	Arka Manik, Asahi Yamato, Pusa Bedana, Durgapur Kesar, Sugarbaby, Durgapur Meetha, Improved Shipper, Special No.1.
Musk melon	Pusa Sharbati, Pusa Madhuras, Hara Madhu, Punjab Sunehari, Sel-2, Arka Jeet, Arka Rajhans, Lucknow Safeda, Durgapura Madhu, RM-43, IIHR-352, IIHR-190, Edisto, Honeywdew.
Long melon	Arka Sheetal, Punjab Long Melon
Cucumber	Japanese Long Green, Straight Eight, Poinsette, Poona Khira, Balam Khira, Swarn Poorna, DVRM-1, IIHR-177-1.
Pumpkin	Arka Suryamukhi, Pusa Vishwas, CM-14
Summer squash	Hisar Sel-1, Patty Pan, Early Yellow Prolific, Australian Green, Punjab Chappan Kaddo-1.
Winter squash	Arka Chandan, CO-1, CO-2
Bottle gourd	Pusa Summer, Prolific Long, Pusa Summer Prolific Round, Pusa Naveen, Arka Bahar, CO-1, Punjab Round, Punjab Long, Punjab Komal, NDBG-1, KBG-13.
Bitter gourd	Coimbatore Long, Arka Harit, VK-1, Priya, PMC-84, MDU-1, CO-1, Konkan Tara, Pusa Do Maushmi, Kalyanpur Sona, Pusa Vishesh, Punjab-14, NDB-1, Phule BG-6.
Ridge gourd	Pusa Nasdar, CO-1, Arka Sumeet, Konkan Harita PKM-1, Punjab Sadabahar, Satputia
Sponge gourd	Pusa Chikni
Tinda	Arka Tinda, Punjab Tinda, S-48.
Ash gourd	CO-1, CO-2
Snake gourd	CO-1, CO-4, TA-19
Pointed gourd	Swarna Alaukik, Swarna Rekha, FP-1, FP-3, FP-4
Pea	Ageta-6, Arkel, Early Badger, Little Marvel, Early December, Bonneville, T-19, Lincoln, Delwiche Commado, NP-25, Perfection New Line, Thomas Laxton, Alderman, GC-141, GC-195, Kawari, Sylvia, Harbhajan, GC-477, Pant Uphar, P-88, VL-3, JP-4.
French bean	Boundiful-Plantifur, Contender, Premier King Green, Blue Lake Kentucky Wonder, Arka Komal, VL Boni-1, Pant Anupma

Contd...

Name of the crop	Important varieties
Cowpea	Pusa Phalguni, Pusa Barsati, Pusa Dofasli, C-152, S-1552, S-203, Arka Garima, Sel-2-1, Red Seeded selection.
Dolichos bean	Pusa Early Prolific, JDL-37, Kalyanpur T-1, Arka Jay, Arka Vijay
Cluster bean	Pusa Navbahar, Sharadbahar, P-28-1-1, CP-78, CO-160-1
Sem	CO-1, CO-2, 125-36 Wal Konkan-1, Hebbal Avare-3
Cauliflower	Punjab Kunwari, Pusa Deepali, Improved Japanese, Pusa Synthetic, Snow ball-16, K-1, Early Kunwari, Pant Gobhi-3, Pusa Early Synthetic, Pant Gobi-2, PG-26, PG-35, Hisar-1, IIHR-101, IIHR-105, Pant Subhra, Pusa Subhra, Pusa Himjyoti, Pusa Katki, Pusa Snowball-1, Pusa Snowball-2, Pusa Snowball K-1.
Cabbage	Golden Acre, Pusa Mukta, Pride of India, Copenhangen Market, Pusa Drumhead, Late Large, Drum Head, Red Cabbage, Golden Eve
Knol-khol	White Vienna, Purple Vienna, King of North, Early White Vienna, Large Green
Radish	Pusa Chetki, Pusa Desi, Pusa Reshmi, Japanese White, Punjab Safed, Kalyanpur No-1, CO-1, Arka Nishant, Chinese Pink, HR-1, Red Tail Radish
European type	Pusa Himani, White Icicle, Rapid Red White tipped, Scarlet Globe, Scarlet Long
Turnip (Asiatic type)	Pusa Kanchan, Pusa Swati, Punjab Safed-4, Early Milan Red Top
European (Temperate type)	Purple Top, White Globe, Goldenball, Snowball, Pusa Chandrima, Pusa Swarnima
Carrot (Asiatic type)	Pusa Keshar, Pusa Meghali, Sel-233, No-29
European type	Nantes Half Long, Early Nantes, Chantenay, Imperator Zeno, Pusa Yamdagni
Onion red	Agri Found Dark Red, Agri Found Light Red, Pusa Red, Punjab Selection, Pusa Ratnar, N-2-4-1, Arka Niketan, Arka Kalyan, Pusa Madhvi, Punjab Red Round, Kalyanpur Red Round, Hisar-2, Arka Pragati, N-53, Udaipur 101, Udaipur-103, VL-3, Arka Bindu, Basant-780, Agrifound Red Rose
Yellow	Early Grano, Spanish Brown
White	Pusa White Flat, Pusa White Round, Udaipur-102, Punjab-48, N-257-9-1
Garlic	Agrifound White-G-41, Yamuna Safed (G-1), G-50, G-282, Agrifound Parvati (G-313). IC-49373, IC-49382, T 86/Sel-1, EC-198250
Amaranth	Pusa Early Bunching, Bari Chaulai, CO-1, CO-2, CO-3, CO-4, Pusa Kirti, Pusa Kiran
Spinach	All Green, Palak Green, Pusa Joyti, Pusa Harit, Jabner Green, HS-23, Palak No 51-16

Source: http://www.icar.org.in/Directorate1.htm#open

TABLE 4
Hybrid varieties of vegetable crops

Crop	Important varieties
Brinjal (Long)	Pusa hybrid-5, NDBH-6, NDBH-7, HOE-404, Pant hybrid-1, ARBH-201, HOE-414
Brinjal (Round)	Pusa Hybrid-6, Pusa Hybrid-9, ARBH-216, NDBH-1, NDBH-8, Neembaker, Pant hybrid-2, BH-1, BH-2, HOE-44, CHRBH-1, CHRBH-2
Brinjal (Small Round)	MHB-10, MHB-39, ABH-1, ABH-2, Hybrid-2, Sumex-9, Sumex-19, HOE-4
Tomato (Determinate)	Pusa hybrid-2, NA-501, DTH-4, NDTH-1, Phule Hybrid-1, BSS-39, ARTH-3, NA-701, ARTH-15, Hybrid No-37, Swarna-12, NDTH-6, HOE-606, NA-701, Maitri, Rishi, HOE-616
Tomato (indeterminate)	ARTH-4, MTH-6, NA-601, Arka Vardhan, KT-4, FMH-1, BSS-20, BSS-40, BSS-90, HOE-909, Larica, Ratna, DTH-6, Sonali, ARTH-16, FM-2, NDTH-2, NDTH-4, TC-161
Chilli	Agni, HOE-808, HOE-888, HOE-818, CH-104, BSS-138, BSS-141, CH-1 (MSIs x LSS), ARCH-228
Capsicum	Bharat, Early Bonty, Indira, Lario, HOE-801, Hira
Cabbage	Pusa Synthetic, Sri Ganesh Gol, BSS-32, Quisto, Nath-401, NATH-501, Uttam.
Cauliflower	Pusa Hybrid-2
Watermelon	Arka Jyoti, Nath-102, MHW-6, Nath-202, MHW-11
Muskmelon	Punjab hybrid-1, MH-10, Pusa Rasraj (M-3), DMH-4, MHY-3, MHY-5
Pumpkin	Pusa Hybrid-1
Cucumber	Pusa Sanyog, Solan Hybrid-1, PCUC-1-1, AAUC-1, AAUC-2
Squash	Pusa Alankar
Bottle Gourd	Pusa Manjari, Pusa Meghdoot, NDBH-7, NDHGH-4, Pusa Hybrid-2, PBOG-2, PBOG-1
Carrot	Hybrid-1

Source: http://www.icar.org.in/Directorate1.htm#open

TABLE 5
List of Indian varieties

(i) Garden pea	variety 'Arkel' has revolutionised the production of early peas in all pea growing areas.
(ii) Cauliflower	variety 'Pusa Early Synthetic' has adapted to warm climatic conditions

Contd..:

	of Tamil Nadu and has made it possible to grow cauliflower commercially in this non-traditional area.
(iii) Watermelon	variety 'Sugar Baby' has spread fast in entire Northern and Eastern India and has benefitted both the growers with better remuneration and the consumers witth better remuneration and the consumers with superior quality. Another variety 'Arka Manik' has made a dent in the Southern and South-Western parts of the country.
(iv) Okra	variety 'Pusa Sawani' bred for resistance to yellow vein mosaic virus prone areas/seasons replaced all other local varieties from cultivation all over the country.
(v) Tomato	variety Pusa 'Sel-120' has made it possible to achieve high yields of quality produce in root-know nematode infested soils. With the released of cold tolerant variety 'Pusa Sheetal', we can now grow tomatoes all the year round.
(vi) Radish	with appropriate choice of suitable varieties for specific seasons now we can grow radish round the years.
(vii) Onion	Until 1978, Kharif onion cultivation was only grown in Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu. However, identification of variety N-53 and ADR and development of technology for kharif onion has enabled to get two crops of onion annually in Northern India where it used to be only a winter/spring crop.
(viii) F1 Hybrids	There has been an allround appreciation of growing of F1 hybrids in vegetable crops. Sizeable area of 20,000 ha. is estimated to be covered under tomato hybrids in Karnataka, Maharashtra & Southern Gujarat. Similarly the area under F1 hybrid of cabbage is estimated at about 8,000 ha.

Source : Current status of vegetable research in India by A.S. Sidhu, PAU.

TABLE 6

List of Vegetable Varieties /Hybrids resistant/ Tolerant to biotic and abiotic stress, rich in nutrition and suitable for processing and export

	Crop	Variety/ Hybrid	Remarks
Resistant/ Tolerant To pests	Tomato	Arka Vardan	Resistant to root knot nematode
	Pumpkin	Arka Suryamukh	Resistant to pumpkin fruit fly
Resistant/ Tolerant	Tomato	Arka Ashish	Tolerant to powdery mildew
to diseases	Tomato	Arka Alok	Resistant to bacterial wilt
	Tomato	Arka Abha	Resistant to bacterial wilt
	Tomato	Arka Shreshta	Resistant to bacterial wilt
	Tomato	Arka Abhijit	Resistant to bacterial wilt
	Brinjal	Arka Nidhi	Resistant to bacterial wilt

Contd...

Brinjal	Arka Keshav	Resistant to bacterial wilt
Brinjal	Arka Neelkanth	Resistant to bacterial wilt
Chilli	PMR 57/88k	Resistant to powdery mildew
Watermelon	Arka Manik	Resistant to powdery mildew, downy mldew and anthrancose
Muskmelon	Arka Rajhans	Resistant to powdery mildew
Okra	Arka Abhay	Tolerant to YVMV
Okra	Arka Anamika	Tolerant to YVMV
French bean	Arka Bold	Resistant to Rust
Garden Pea	Arka Ajit	Resistant to powdery mildew and rust
Onion	Arka Kalyan	Tolerant to purple blotch
Onion	Arka Kirthiman	Tolerant to purple blotch, basal rot and thrips
Onion	Arka Lalima	Tolerant to purple blotch, basal rot and thrips
Amaranth	Arka Suguna	Resistant to white rust.

Source : Technical Bulletin-Vegetable Varieties/ Hybrids of IIHR, 2004.

TRANSGENIC CROPS

Transgenics in Vegetable Crops

Although having little impact in vegetable crops at present, transgenes (used to create genetically modified organisms or GMOs) do have potential, particularly in the arena of providing genetic resistance to insects. There is at present, a dichotomy in agriculture with regard to GMOs. Creation of GMO cultivars for major crops actively continues, while research and development of GMO cultivars in the minor crops has lagged. The reasons for this are complex, and have political and social, as well as technical roots. Some GMO vegetables have been released. These include ripening inhibitor tomatoes, virus resistant summer squash, and earworm resistant sweet corn. Of these, sweet corn containing the BT toxin gene is probably the most valuable because it has been exceedingly difficult to achieve earworm resistance through natural means. For the other examples above, naturally occurring genes are known, obviating the need to use a transgenic strategy.

With characterization of more number of viral genes from different viruses , development of transgenic for viruses resistance has taken a central stage for the management of viral diseases. Many viral genes are fully characterized and different strategies have been developed to utilize them as transgenes for development of transgenics. Among them, important viral gene(s) are : replication initiator protein (rep) gene of Tomato leaf curl virus (Sinha *et al.*, 2004), coat protein (CP) gene of Papaya ring spot virus, cucumber mosaic virus, and Tobacco streak virus (Bhat *et. al.*, 2002), and nucleocapsid protein gene of Groundnut bud necrosis virus (Umamaheshwaran et.al., 2003). Besides

these viral genes, many conserved sequences have been characterized and will be targeted through the phenomenon the phenomenon of RNA interference.

Transgenic tomato resistant to tomato leaf curl disease (ToLCD) using replicase (rep) gene sequences of Tomato leaf curl virus in antisense orientation were developed via Agrobacterium- mediated transformation. High level of resistance and inheribility of the transgene has been observed up to T2 stage following challenge inoculation with the virus Progeny analysis of these plants showed classical Mendelian pattern of inheritance in two of the six transgenic lines having single transgene insertion. The mechanism of resistance appears to be RNA- mediated, since transforming Tomato leaf curl virus-infected plants with the homologous rep gene constructs that produce RNAs capable of duplex formation confers gene silencing and results in recovery of infected plants. The intense suppression in the virus- infected plants provides a threshold level of dsRNA needed to induce gene silencing leading to the virus suppression (Praveen *et. al.*, 2005*b*). The first virus resistance transgenic tomato has been planted in the field during the Centenary Year in IARI, New Delhi.

Coat protein mediated transformation has been achieved in elite cultivars of papaya through Agrobacterium (Sharma *et. al.*, 2004). Transformed lines are at various stages of testing. Similarly, coat protein and nucleocapsid protein genes seem to be promising in developing virus resistance in cucumber and tomato respectively.

It is important to place genetic resistance into the perspective of the whole cropping system. Resistance alone is not the sole means to achieve a pest-free crop, and may lead to more rapid loss of the utility of resistance genes. One must use a resistant cultivar as part of an integrated system of cultural management.

WHAT ARE TRANSGENIC PLANTS

Transgenic plants are plants that possess gene or genes that have been transfered from a different species. They can arise by natural movement of genes between species, by cross-pollination based hybridisation between different plant species (which is a common event in flowering plant evolution), or by laboratory manipulations to insert additional genes, commonly occuring during Genetic Engineering using recombinant DNA techniques to create plants with new characteristics by artificial insertion of genes from another species.

Prior to the current era of Molecular genetics starting around 1975, transgenic plants including cereal crops were (since the mid 1930s) part of conventional Plant breeding.

Transgenic varieties are frequently created by classical breeders who deliberately force hybridisation between distinct plant species when carrying out interspecific or intergeneric *wide crosses* with the intention of developing disease resistant crop varieties. Classical plant breeder may use a number of *in vitro* techniques such as protoplast fusion, embryo rescue or mutagenisis to generate diversity and produce plants that would not exist in nature.

These "classical" techniques (used since about 1930 on) have never been controversial, or been given wide publicity except among professional biologists, and have allowed crop breeders to develop varieties of basic food crop, wheat in particular, which resist

devastating plant diseases such as rusts. ***Hope*** is one such transgenic wheat variety bred by E. S. McFadden with a transgene from a wild grass.

Methods used in traditional breeding that generate transgenic plants by non-recombinant methods are widely familiar to professional plant scientists, and serve important roles in securing a sustainable future for agriculture by protecting crops from pest and helping land and water to be used more efficiently.

Deliberate creation of transgenic plants during breeding

. Production of transgenic plants in wide-crosses by plant breeders has been a vital aspect of conventional Plant breeding for a century or so. Without it, security of our food supply against losses caused by crop pests such as rusts and mildews would be severely compromised. The first historically recorded interspecies transgenic cereal hybrid was actually between wheat and rye (Wilson, 1876).

Introduction of alien germplasm into common foods was repeatedly achieved by traditional crop breeders by artificially overcoming fertility barriers throughout the last century, and novel genetic rearrangements of plant chromosomes, such as insertion of large blocks of rye (Secale) genes into wheat chromosomes ('translocations'), have also been exploited widely for many decades.

By the late 1930s with the advent of drug Colchicine, perennial grasses were being hybridized with wheat with the aim of transferring disease resistance and perenniality into annual crops, and large-scale practical use of hybrids was well established, leading on to development of Triticosecale and other new transgenic cereal crops.

The intentional creation of transgenic plants by laboratory based recombinant DNA methods is more recent (from the mid-80s on) and has been a controversial development opposed vigourously by many NGOs, and several governments, particularly within the European Community. These transgenic recombinant plants (= biotech crops, modern transgenics) are transforming agricultural productivity in those regions that have allowed farmers to adopt them, and the area sown to these crops has continued to grow globally in each of the ten years since their first introduction in 1996.

Transgenic recombinant plants are now generally produced in a laboratory by adding one or more genes to a plant's genome,and the techniques frequently called transformation. Transformation is usually acheived using gold particle bombardment or a soil bacterium (*Agrobacterium tumefaciens*) carrying an engineered plasmid vector, or carrier of selected extra genes.

Transgenic recombinant plants are identified as a class of genetically modified organism(GMO); usually only transgenic plants created by direct DNA manipulation are given much attention in public discussions.

Transgenic plants have been deliberately developed for a variety of reasons: longer shelf life, disease resistance, herbicide resistance, pest resistance, non-biological stress resistances, such as to drought or nitrogen starvation, and nutritional improvement. The first modern transgenic crop approved for sale in the US, in 1994, was the FlavrSavr tomato, which was intended to have a longer shelf life. The first conventional transgenic cereal created by scientific breeders was actually a hybrid between wheat and rye in 1876

(Wilson, 1876). The first transgenic cereal may have been wheat itself, which is a natural transgenic plant derived from at least three different parental species.

Commercial factors, especially high regulatory and research costs, have so far restricted modern transgenic crop varieties to major traded commodity crops, but recently R&D projects to enhance crops that are locally important in developing countries are being pursued, such as insect protected cow-pea for Africa, and insect protected Brinjal eggplant virus resistance in vegetable crops for India.

MODERN TRANSGENIC CROPS AND THEIR ADVANTAGES

In 2005, there were more than 90 million hectares of transgenic plants created by recombinant DNA methods being grown throughout the world by some 8.5 million farmers. There are five general types of transgenic plants:

(i) those with genes to improve the quality of the product.

(ii) those with genes to allow them to resist disease or herbivory (consumption by herbivores, usually insects).

(iii) plants with genes that allow them to be resistant to the effects of specific herbicides.

(iv) plants with genes conferring resistance to environmental conditions that cause crop losses (extremes of cold, heat, drought,salt concentration, etc.).

(v) A developing group of transgenic plants is that of nutraceuticals, or plants designed to possess properties that make them healthier in specific ways. Examples include The Golden Rice that produce higher concentrations of specific compounds like beta carotene.

An emerging class of transgenic plant increasingly created by modern methods, sometimes known as pharmacrops, aims to use plants to manufacture other products, such as pharmaceuticals and industrial chemicals. Testing of a variety of these crops has been underway for several years, and they include transgenic rice developed by a Californian company to improve oral rehydration therapy for diarrohea.

A recent study in Peruvian Hospital has demonstrated that specialized milk proteins lactoferrin and lysozyme made in transgenic rice plants improve the effectiveness of oral rehydration solution used to treat diarrhea. Industrial transgenic crops will be important for biofuel production and for agricultural substitutes for petrochemicals such as plastics.

There has been rapid uptake of modern transgenic cotton varieties in India. This has been associated with a dramatic improvement in the Indian cotton industry's productivity, with national average yield increases approaching a 50% improved yield per hectare above the long term average yield, because the transgenic trait Bt insect resistance has both encouraged the adoption of better performing hybrid cotton varieties, and also prevented loss to insect predation.

The main modern transgenic crop is soybean, widely grown in North and South America. At that time, 60% of the the worlds soybeans, 28% of the world cotton 18% of canola (rapeseed) and 14% of world corn being grown are transgenic. Last year transgenic rice (Bt) was also grown commercially for the first time on approximately four thousand hectares in Iran by several hundred farmers.

Rice is the most important food crop in the world, grown by 250 million farmers, and the principal food of the world's 1.3 billion poorest people. Commercialization of transgenic recombinant rice has huge implications for the alleviation of poverty, hunger, and malnutrition. Iran and China are the most advanced countries in this area, and China has already substantially field tested modern transgenic rice in pre-production trials.

The insect resistance transgenic traits (typically various Bt (= Cry) proteins from *Bacillus thuringiensis* species of bacteria) have greatly reduced spraying of synthetic chemical pesticides in the cotton industry, a major user of these chemicals.

Biotechnology corporations have several new transgenic crop traits in the R&D pipeline, most notably improvement in nutritional properties of vegetable oils from presence of Omega 3 polyunsaturated fatty acids, and improvements to crop, water use efficiency and drought tolerance.

ECOLOGICAL RISKS

The potential impact on nearby ecosystems is one of the greatest concerns associated with transgenic plants but most domesticated plants mate with wild relative of some location where they are grown, can the have potentially harmful consequences such as:

1. evolution of increased weediness
2. increased likihood of extinction of wild-relatives.

Transgenes (and traits present in domesticated crop created by conventional breeding) have the potential for significant ecological impact if the plants can increase in frequency and persist in natural populations. This can occur:

- if transgenic plants "escape" from cultivated to uncultivated areas.
- if transgenic plants mate with similar wild plants, the transgene could be incorporated into the offspring.
- if these new transgene plants become weedy or invasive, which could reduce
- if the transgenic crop trait confers a selective advantage in natural environments

Gene flow may affect biodiversity and might affect entire ecosystems.

Pollen flow from conventional crop plants to native species also poses gene-flow derived ecological risks, as crop plants are not selected to have optimal selective advantages in natural environments, and farm fields are different to natural ecosystems. Conventional varieties also posess new traits such as pest resistance that have been deliberately transferred into the crop variety from other species.

There are at least three possible avenues of hybridization leading to escape of a transgene:

1. Hybridization with non-transgenic crop plants of the same species and variety.
2. Hybridization with wild plants of the same species.
3. Hybridization with wild plants of closely related species, usually of the same genus.

However, there are a number of factors which must be present for hybrids to be created.

- The transgenic plants must be close enough to the wild species for the pollen to reach the wild plants.
- The wild and transgenic plants must flower at the same time.
- The wild and transgenic plants must be genetically compatible.
- The hybrid offspring must be viable, and fertile.
- The hybrid offspring must carry the transgene.

Studies suggest that a possible escape route for transgenic plants will be through hybridization with wild plants of related species.

1. It is known that some crop plants have been found to hybridize with wild counterparts.
2. It is understood, as a basic part of population genetics, that the spread of a transgene in a wild population will be directly related to the fitness effects of the gene in addition to the rate of influx of the gene to the population. Advantageous genes will spread rapidly, neutral genes will spread with genetic drift, and disadvantageous genes will only spread if there is a constant influx.
3. The ecological effects of transgenes are not known, but it is generally accepted that only genes which improve fitness in relation to abiotic factors would give hybrid plants sufficient advantages to become weedy or invasive. Abiotic factors are parts of the ecosystem which are not alive, such as climate, salt and mineral content, and temperature.

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7

INTEGRATED PEST MANAGEMENT MODULES

INTEGRATED PEST MANAGEMENT SYSTEM

In 1967, a FAO (Food and Agriculture Organisation of the United Nations) panel of experts defined IPM as: "A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury."

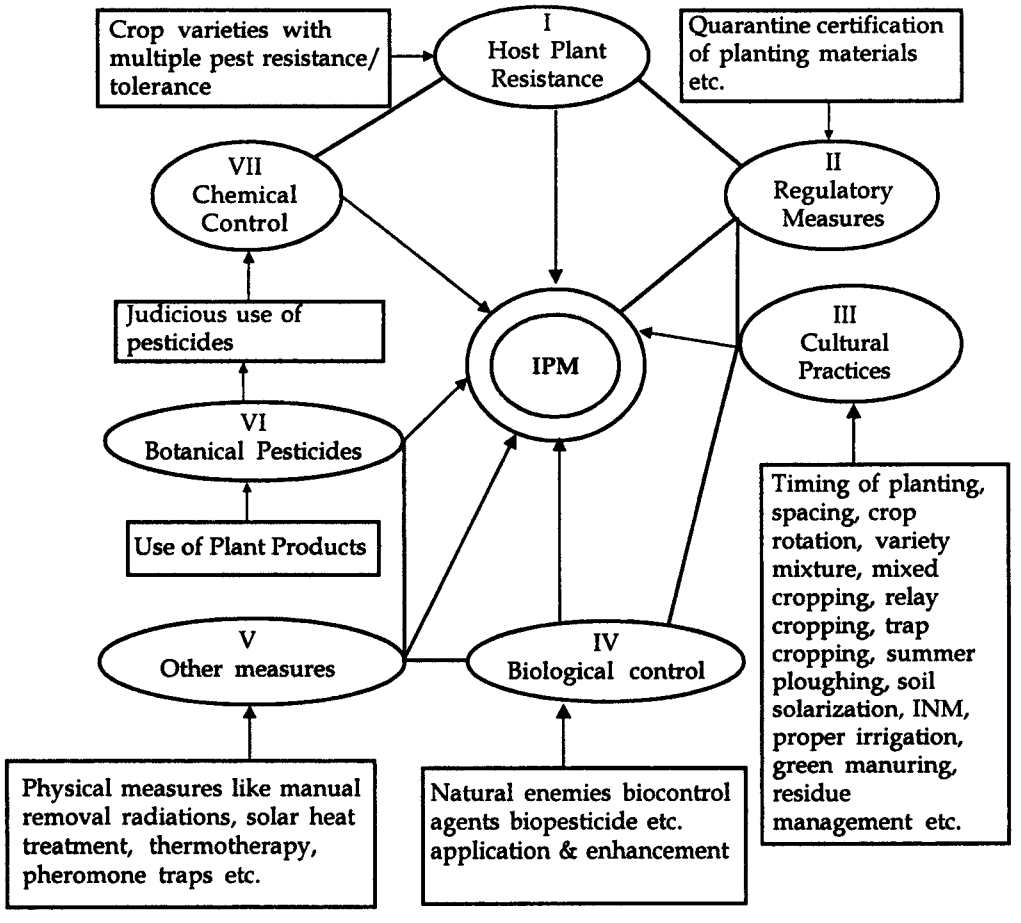
IPM emphasizes the need for simpler and ecologically safer measures for pest control to reduce environmental pollution and other problems caused by excessive and indiscriminate use of pesticides.

The present system of agriculture is largely governed by a policy of economic development that primarily emphasizes high productivity for commercial purposes. This has led to programmes of agricultural intensification involving widespread planting of high input response varieties cultivars (high yielding are mostly pest susceptible), expanding areas under monoculture, shortening fallow periods and the intensive use of agrochemicals. The strategy adopted by food industry and most international and national agencies have made extensive efforts for improved crop varieties and intensive use of energy based inputs such as fertilizers and pesticides to create higher yields on existing lands. In many agricultural systems the unilateral approach of chemical pest control has generated many undesirable effects, such as, increasing insect outbreaks induced by pesticides, rapid development of resistance by pests to the chemicals used against them, becoming trapped in pesticide treadmills, decline in biodiversity, degeneration in natural resources, agrochemical pollution and damage caused to the environment, human laden hazards and matters related to international trade, sustainablity in food production and food security.

As a result there have been arguments for food production and security to be viewed in the context of sustainable agriculture and need for investment in low extended input had non chemical alternatives that included farmer empowerment.

IPM is the use of a combined set of strategies practices aimed to keep pests at levels under the economic damage threshold. The term IPM coined by entomologists in the mid-1960s, was developed in order to reduce the risks associated with excessive use of pesticides and to preserve the ecological balance (Smith and Bosch, 1967). As pointed out by Jacobson (1977), this approach presumed that pests, like insects quantification and their detection is easier as compared to other plant pathogens. From the view of systems science, IPM is systematic science dealing with a wide range of hosts, pests, environments and socioeconomic components. IPM attempts to integrate the available pest control methods to achieve a farmer's most effective, economical and sustainable combination for a particular local situation.

The IPM & its subsystems



Emphasis is placed on biological control, plant resistance, cultural control and other non polluting methods. Pesticides to be used as need based and only when cost benefit ratio show their justified use (Fig. 1 IPM and its subsystems). Importantly required in this system is the compatibility of all the practices with each other. Any practice applied for eg. Compatibility of the bioagent with a pesticide timely application, accurate dosages and detection of damage. IPM involves healthy crop production practices in the form of cultural practices, integrated nutrient management, selection of crop variety seed treatment, appropriate cultural practices.

Based on detection of pests are the crop protection technologies including :

(a) mechanical removal of pests diseased plants.

(b) use of traps and mating disruptions.

(c) Application and promotion of biological control agents and biopesticides.

(d) Botanical pesticides viz Neem, Karanj.

(e) Need based use of chemical pesticides.

The parameters governing sustainable agriculture are characterized by their ecological compatibility which ultimately would provide production stability and while designing viable integrated pest management strategies, such ecological compatibilities are taken lately sharp focus. As seen in table 1 some practices are sustainable, employing external inputs and also utilizes labour input.

TABLE 1

Inputs needed in integrated disease management for sustainable production

Practice	Sustainable	External inputs	Labour
Adjusting Crop Density	Yes	Low	Low
Adjusting Depth of Planting	Yes	Low	Low
Adjusting Time of Planting	Yes	Low	Low
Altering of Plant and Crop architecture	Yes	Low	High
Biological Control	Yes	High	High
Fallowing	Yes	Low	Low
Flooding	Yes	Low	High
Mulching	Yes	High	High
Multiple Cropping	Yes	Low	High
Planting diverse crop	Yes	Low	Low
Planting in raised beds	Yes	High	High
Rotation	Yes	Low	Low
Tillage	No	Low	High
Using organic amendments	Yes	High	High
Weed control	No	Low	High
Solarization	No	High	High
Nylon net	Yes	High	High

Jalali and Jalali 2002

With the adoption of IPM by the farmers, the consumption of chemical pesticides in India has come down from 61,357 MT (Tech. Grade) during 1994-95 tp 39,773 MT (Tech Trade) during 2005-06. Adoption of IPM by the farmers over larger acreage and the thrust on organic farming may further reduce the use of chemical pesticides and simultaneously increase the requirement of bio control agents and biopesticides. Apparently there is a need to increase the availability of these critical IPM inputs.

IPM aims at

An integrated strategy for crop pest management includes use of resistant varieties, modifying agronomic practices to evade and reduce pest incidence, biological control and other novel approaches for pest suppression and only need based judicious use of chemical pesticides.

Basic components of IPM are

- Cultural Methods
- Biological Methods
- Chemical Methods

CULTURAL METHODS

Use of organic manures and biofertilizers

Disease free planting materials

Quarantines and Inspections

Use of Pathogen-Free Propagating Material

Pathogen-Free Seed

Nursery methods

Sanitation

Creating Conditions Unfavorable to the Pathogen

Solarization

Polyethylene Traps and Mulches

CHEMICALS METHODS

Direct Protection by Chemical Controls

Foliage Sprays and Dusts

Seed Treatment

Soil Treatment

Treatment of Tree Wounds

PESTICIDE RESIDUES

Pesticides are one of the important inputs in modern agriculture for protecting the crops from pests and diseases .When used they may leave some residues on the treated crops from pest and diseases. If these residues are within safe limits, then are safe to health of human beings and animals. However, their presence beyond certain level of residues which can be permitted on particular crop for each pesticide. This level/ limit is called "Maximum Residue Limit"(MRL). MRLs are the levels of pesticides than can

be ingested daily by man without appreciable risk. A pesticide residue is defined as the combination of the pesticide and it's metabolites, degradates and other transformation products on human foods, livestock feeds and /or drinking water. This residue definition is used to set and enforce MRLs and to assess the dietary risk by determining the parent compound and it's toxicologically significant metaboltes.The basic requirements for the definition of residues are that it should include compounds of toxicological interest for dietary intake estimations an risk assessment.MRLs are the concentrations and are food specific. These are monitoring tools for Good Agricultural Practices.

Singh 2006 highlighted these values in his lecture as Environmental Impact Quotient, Based on Indexes of impact on form worker, consumer and ecological component (Leaching, effect on flora and fauna etc.) which helps in understanding the hazardous effect of pesticides, expressed in following tables. Such type of values needs to be calculated so that a full package of IPM can be developed.

TABLE 2

Hazard levels of pesticides expressed as EIQ*

S.No.	Pesticide Name	EIQValue	Effect on Farm Worker	Effect on Consumer	Effect on Environment
Organochlorine					
1.	Lindane	69.20	72.00	15.08	120.08
2.	Endosulphan	42.10	36.00	7.00	27.00
3.	Dicofol	29.90	36.00	5.00	48.55
Organophosphorus					
1.	Dimethoate	74.00	72.00	9.00	140.90
2.	Phorate	68.20	40.00	10.00	154.60
3.	Monocrophos	53.30	78.00	18.00	64.00
4.	Fenitrothion	47.30	78.00	6.00	58.00
5.	Chlorofenvinphos	43.90	37.20	6.20	88.20
6.	Chloropyriphos	43.50	18.00	4.00	108.55
7.	Prophenophos	42.00	48.00	4.00	74.00
8.	Ethion	41.00	34.50	2.5	86.20
9.	Dichlorvos (DDVP)	40.60	60.00	3.00	58.75
10.	Acephate	23.40	12.00	11.0	47.15
Carbamate					
1.	Propoxyr	87.30	72.00	13.00	176.80
2.	Carbofuran	50.67	60.00	17.00	75.00
3.	Cartap Hydrochloride	34.00	48.00	12.00	42.00

Contd...

S.No.	Pesticide Name	EIQValue	Effect on Farm Worker	Effect on Consumer	Effect on Environment
4.	Methomyle	30.70	6.00	11.00	75.00
5.	Carbosulphan	25.30	12.00	10.00	54.00
6.	Carbaryl	21.70	9.00	2.50	53.70
Pyrethroids					
1.	Permethrin	88.70	20.00	9.00	237.00
2.	Oxydemeton-Methyl	75.03	80.00	17.00	128.10
3.	Fenvalerate	49.60	8.00	4.00	136.75
4.	Cyhalothrin	43.50	21.00	3.45	106.45
5.	Cyfluthrin	39.60	7.00	3.45	108.35
6.	Cypermethrin	27.30	9.00	4.00	69.00
7.	Pyrethrins (Pyrethrum)	18.00	6.00	3.00	44.95
Benzoylurea					
1.	Diflubenzuron	25.33	8.00	3.00	65.00
Chloro-nicotinyle					
1.	Imidacloprid	34.00	7.00	7.35	87.47
Microbial & Botanicals					
1.	Spinosad	17.70	6.00	2.00	45.15
2.	Azadirachtin (Neem Product)	12.80	6.00	2.00	30.30
3.	Bacillus thuringiensis (Bt & Bs)	7.90	6.00	2.00	15.75
Anilid					
1.	Corboxin	20.00	9.00	5.50	45.40
Dinitroaniline					
1.	Trifluralin	41.20	24.00	5.50	42.00
Trizole					
1.	Hexaconazole	40.30	27.00	53.50	40.50
Banned (Indian Examples)					
1.	Chlordane	63.60	62.10	11.40	117.40
2.	Aldicarb	37.10	45.00	14.10	52.40

*Environmental Impact Quotient, Based on Indexes of impact on farm worker, consumer and ecological component (Leaching, effect on flora and fauna etc.)

EIQ={[(C(DTx5)+(DTxP)I+I(Cx(S+P)/2xSY)+(L)I+I(FxR)+(Dx(S+P)/2x3))+(ZxPx3)+(BxPx5)]}/3 SOURCE :Amerika Singh 2006 Current Status Of IPM R & D and A Road Map For IPM Movement. in Brainstorming on Integrated Pest Management and Biopesticides (26 April,2006).

Pesticide residue free IPM packages for vegetables

Research has been carried out to develop a package for integrated crop management so as to prevent pathogens, insects and weeds from causing economic crop losses by using a variety of management practices right from cultural to crop protection. With the integration of the Boagents the IPM package can very well work with a sustainable effect.

Some examples of Integration of Bioagents with other plant protection methods

Chilli *(Capsicum annuum* L) also called red pepper is an important cash crop of India and is grown for its pungent fruits, which are used both green and ripe (the latter in the dried form) to impart pungency to food. Cabbage (*Brassica oleracea* L. var. *capitata)* is important vegetable crop of the cole group, which is grown in all regions of the country. Tomato (*Lycopersicon esculentum* Mill) crop is ravaged by sucking pests like white flies (*Bemisia tabaci*) and thrips (*Thrips tabaci*) as well as fruit borers, *Helicoverpa armigera* and *Spodoptera litura.* The important insects pests and diseases identified in Delhi region followed by their management are presented below.

IPM package for Delhi & surrounding region, the packages were then evaluated from (i) yield as well as (ii) pesticides residue point of view and the refined IPM package was proposed for adoption and continuing evolutionary improvement with time and research capabilities.

Under the PSR-NATP entitled "Development of pesticide residue free IPM packages for vegetables" team consisting of Plant Pathologist, Entomologist and Agricultural Chemists developed the following IPM modules for chilli, cabbage and tomato at IARI, New Delhi.

SOME EXAMPLES OF IPM PACKAGES

IPM schedule for Chilli crop

Stage	Operation	Target pest
Nursery preparation	Soil solarization. (May-June)	Soil borne.
Seed treatment	*T.harzianum* @ 4 gm/kg seed.	Damping off
Nursery	Soil application of carbofuron @ 0.5 kg a.i./ha.	Sucking pests
	Sowing of chilli	
	Covered nursery beds with nylon nets	Vectors
	Drenching nursery beds with COC* @ 3 gm/litre	Damping off.
Before transplanting	Carbendazim (2gm/l) for ½ hr.	Fungal pathogens.
	Imidacloprid @ 0.3 ml/lit. for ½ hr. (Seedling dip)	Aphids, white fly.
Transplanting	Soil drenching with chloropyrifos.	Termites
	Applied COC @ 3gm/litre	Anthracnose
	Spray of neem oil @ 5ml/litre	Aphids & white fly
	Spray T.harzianum @ 4 gm/litre	Anthracnose

Contd...

	Installation of pheromone trap	Lepidopterian pest (Helicoverpa, Spodoptera)
	Dimethoate @ 2.5 ml/litre	Aphids & Borers
	Acephate + Pongamia oil + laboleen sticker (0.5gm formulation + 2 ml + 0.5 ml) /litre	Borers
	COC @ 3gm/litre	Anthracnose
	Thiophanate Methyl @ 1gm/litre	Fruit rot
	Neemarin @ 4 ml/litre	Anthracnose, Aphids & white fly.
	Spray of NSKE** @ 5%	Fruit borer. Aphids & white fly
	Spray of chlorothalonil @ 600 gm a.i./ha.	Anthracnose

IPM module for cabbage:

Stages	Operations
Before nursery sowing	
Soil solarisation.	
Application of NSKE @ 50 gm/sq.m.	
T.harzianum @ *4 gm/kg seed and Captan @ 4 gm/kg seed.*	
Nursery sowing	Covered with nylon net (100m width).
Before transplanting	Seedlings dip in Imidacloprid @ 0.02 per cent and *T.harzianum* @ 4 gm/litre
Transplanting	Sprays as follows:-
15 DAT	Imidacloprid @ 0.08 gm/litre
25 DAT	NSKE @ 4 per cent.
35 DAT	*T.harzianum* @ 4 gm/litre
45 DAT	Ridomil @ 1 gm/litre and installation of Pheromones trap.
55 DAT	*Beauveria bassiana* @ 3 gm/litre
65 DAT	*T.harzianum* @ 4 gm/litre
75 DAT	Bavistin @ 0.2 per cent.
85 DAT	Streptocyclin @50 ppm.
95 DAT	Mancozeb @ 0.2 per cent.
105 DAT	Dimethoate @
115 DAT	*T.harzianum* @ 4 gm/litre
125 DAT	Neemarin @ 3ml/litre
135 DAT	Ist harvesting.
142 DAT	IInd harvesting.
150 DAT	IIIrd harvesting.

IPM Schedule For Tomato crop (Winter)

Stage	Operation	Target pests
Nursery	Soil solarization.	Soil insects & diseases
	Marigold (*Tagetes patula*) sown before 15 days to tomato nursery.	
Seed Treatment	Seed Treatment with Captan 2-3gm/kg seed	Damping off
	Soil application of Carbofuron @ 0.5kg a.i./ha.	Soil insects like ants & termites.
Sowing of tomato seed	Covered nursery with nylon net.	Vectors.
At Transplanting	Seedling dip with Carbendazim (2 gm/litre followed by Imidacloprid (0.3ml/litre) for ½ hr.	Fungal pathogen and white fly.
	Neem cake @ 250kg/ha treated with *T.harzianum* 2.5 kg/ha. In the main field	Pathogens
Transplanted crop	Marigold transplantation (trap crop).	
	Imidacloprid spray @ 20 gm a.i./ha.	White fly.
	Pheromone trap and coloured strips	*Helicoverpa armigera, Spodoptera litura* and birds.
	Neemarin spray	Aphids and white fly.
	Imidacloprid spray @ 20 gm a.i./ha.	White fly
	Spray Chlorothalonil 2 0.8 gm a.i./ha	Alternaria
	NPV spray (0.4ml/lit.)	Fruit borer

IPM Schedule For Tomato crop (Summer)

Stage	Operation	Target pests
Nursery	Marigold sown before 15 days to tomato nursery.	*Helicoverpa armigera.*
Seed Treatment	Seed treatment with streptocyclin (10ppm).	Bacterial diseases.
	Soil treatment with captan @ 50 gm/plot.	Damping off.
	Sowing of tomato seed.	
	Covered nursery with nylon net.	Vectors of leaf curl.
	Spray of COC @ 3 gm/litre	Early blight.
At Transplanting	Seedling dip with *T.harzianum* @ 4 gm/litre for ½ hr.	Early blight.
	Soil application of neem cake @ 250 kg/ha with *T. harzianum* @ 2.5 kg/ha.in main field.	Root knot, Damping off, Termites.
Transplanted crop	Marigold transplantation (Trap crop)	*Helicoverpa armigera.*
	Imidacloprid spray 2 20 gm a.i./ha.	White fly (vector of LCV)
	Imidacloprid spray 2 20 gm a.i./ha.	White fly (vector of LCV)

Contd...

Stage	Operation	Target pests
	Pheromone trap	Helicoverpa armigera & Spodoptera litura
	Neemarin spray@ 2.5 ml/litre	Aphids & white fly
	Dimethoate spray@ 2.5 ml/litre	Aphids
	NSKE spray (4%) + carbendazim (2 gm/lit.)	Fruit borer & Spotted wilt virus.
	NPV spray	Fruit borer
	NPV spray	Fruit borer

Source: Development of Pesticide residue free IPM package for Vegetables Final Report PSR-NATP, Division of Agrl Chemicals, IARI, New Delhi-12

Brinjal: Nursery

1. Deep ploughing during summer to expose resting stages of pests to sunlight.
2. Grow resistant varieties
3. Seed treatment with *Trichoderma viride* @ 4g/kg of seed in nursery to prevent seed and spoil borne infection of fungal diseases.
4. Soil solarization using transparent polythene sheets on nursery beds for 2-3 weeks which helps in killing nematodes, weed seeds and resting stages of insect and diseases. Nursery bed should be treated with 10% formalin and covered with polythene for 24 hr.
5. Use of nylon nets in nursery beds to avoid entry of white fly etc. as diseased seedlings or other pests may be carried to main crop.

Main field

1. Collection and destruction of egg masses, larvae and adults of hadda beetle helps in significant reduction of the pest.
2. Use of yellow sticky traps @ 10/ha for sucking pests like white fly etc.
3. Spray of 5% NSKE for sucking pests in early stages.
4. Release of *Trichogramma chilonis* @ 1.0 lakh/ha six times starting from shoot formation stage at weekly intervals brings about significant reduction in fruit borer damage.
5. Regular removal and destruction of damaged shoots and fruits also helps in its significant decrease in incidence.
6. Two alternate sprays of endosulfan @ 0.5 a.i/ha or carbaryl (0.1%) and cypermethrin @ 50 g a.i./ha at 15 days interval for Hadda beetle and shoot and fruit borer (Teotia & Singh, 1970).
7. Roughing of bacterial wilt affected and little leaf of brinjal affected plants.
8. Application of bleaching powder @ 15 kg/ ha before planting against bacterial wilt infection in endemic areas.
9. Destruction of crop residues/debris reduces the carry over load of many insect

pests. After the harvest it should not be allowed to stand in the field and should be immediately destroyed/ploughed in the field.

10. Crop rotation with non-host crops such as sorghum and wheat reduces the root-knot and remiform nematode. Similarly, marigold or onion use also recommended for nematode management.

Potato

1. Deep summer ploughing to expose resting stages of insect etc.
2. Growing of resistant varieties viz., Kufri Swarna, for potato cyst nematode (PCN) in Nilgiris (TN). Kufri Badshah, Kufri Anand, Kufri Kanchan are tolerant to late blight. Kufri Jyoti was tolerant to Wart disease and lateblight. In case very serious nematode problems potato cultivation may be replaced with non-host crops for 2-3 years.
3. Use of disease-free seeds.
4. Adjustment of planting and harvesting time for avoidance of pest and diseases. Optimum planting time for potato is 15th - 30th October in Western and Central Plains and 1st Nov. - 15th Nov. in Eastern plains.
5. Covering of exposed tubers. So prepare high ridges.
6. Use of yellow sticky traps @ 10/ha. for attracting aphids etc.
7. Use of sex pheromone traps for PTM helps in reduction of pest population and monitoring their population. Apply 20 traps/ha for mass trapping.
8. Apply forewarning system to warn the farmers 2-3 weeks in advance for aphids and late blight.
9. Two sprays of monocrotophos @ 1.2 litre/ha. or dimethoate @1/5 litre/ha in 1000 litres of water for PTM and aphids may be sprayed.
10. Rouging of diseased plants.
11. To control late blight copper oxychloride 50% WP or Mancozeb 75% WP @ 2.5 kg/ha is used.

Cabbage: Nursery

1. Adopt raised nursery beds for good drainage to avoid damping off in nurseries as it prevents fungi such as *Pythium, Phytophthora* etc.
2. Seed treatment with *Trichoderma viride* @ 4g/kg in nursery to prevent infection of soil borne/seed borne fungal diseases.
3. Add 50 g of *Trichoderma viride* to 1 kg of FYM. Mix in 1 m^2 of soil.
4. Soak seeds in solution of streptomycin sulphate @ 1g/10 litres for bacterial disease.
5. Soil solarization using transparent polythene sheets in nursery beds for 2-3 weeks.
6. Use of nylonnet in nursery beds to avoid entry of white fly, aphids etc.
7. Spray nursery with *B.t* if DBM is noticed.

Main field

1. Srinivasan and Veerash (1986) recommended one row of cabbage intercropped with one row of tomato (30 days after cabbage) to control DBM and leaf webber.
2. Growing two rows of Indian mustard after every 25 rows of cabbage traps DBM, leaf webber, aphids etc. These can be removed or sprayed with dichlorovas 0.1%. One row of mustard is sown 15 days before cabbage planting and second 25 days after planting of cabbage.
3. Inundative releases of *Trichogrammatoidea bactrae* @ 0.5-0.75 lakh eggs/' ha at weekly interval.
4. *Cotesia plutella* has been found to parasitise larvae of DBM upto 50% in Bangalore . So this holds promise and can be mass multiplied and released in the field.
5. Spray Bt if DBM population around 1/plant is noticed early.
6. Spray NSKE 5% at 20-25 DAP. Repeat if DBM is >2/plant at 10-15 days interval. Maximum of 5 NSKE sprays in one crop season are required. Spray of NSKE should start at head initiation stage.
7. Remove affected bottom leaves if *Alternaria* appears. Spray chlorothaonil if required.
8. Spray Blitox + streptomycin if black rot appears.

Okra

1. Deep summer ploughing is useful to expose resting stages (Pre-sowing).
2. Varieties viz., Punjab-7, Clemson Spineless, AE-22, MP-7 were tolerant against shoot and fruit borer. Parbhani Kranti and Varsha Uphar are tolerant to YVM Virus (Lal, 1991).
3. Intercropping with onion or cowpea is useful. Crop rotation with non-host crops such as sesame; marigold, onion or mustard reduces nematode infestation.
4. Set up yellow sticky traps for monitoring white fly etc. @ 10 traps/ha.
5. Spray of NSKE 5% against jassids during vegetative stage was found to be effective. 3-4 sprays may be given.
6. Installation of pheromone traps for *H. armigera* and *Earias vittella* @ 5 traps/ ha.
7. Release of *T. brasielienses* @ 1-1.5/ha at bud initiation stage at weekly intervals for six times against *Earias vittella.*
8. Spray HaNPV 250LE/ha for *H. armigera.*
9. Removal and destruction of infested shoots and fruits.
10. Rouging of YMV affected plants from time to time and take crop during summer.
11. Spray of monocrotophos EC against jassid and 2 sprays of fenvalerate @ 0.005% against shoot and fruit borer at 15 days interval are effective (Krishna et al., 1989 and Sardana, 1991).

Cucurbitaceous Vegetables

1. Deep summer ploughing to expose the resting stages of the pests and nematodes.
2. MM22-2, Lakhazda, Kharda, IHR selections 40 and 47 are fruit fly tolerant musk melon varieties. Hissar II and Ghote of bitter gourd were found tolerant to fruit fly (Srinivasan, 1991).
3. Seed treatment with *T. viridae* @ 4g/kg of seed.
4. Balanced dose of fertilizers and enough spacing is kept, thus preventing the crop from overlapping.
5. Hand collection and destruction of beetles from plants.
6. Stirring the soil causes mortality of pupal stages of *D. cucurbitae.*
7. Removal and destruction of damaged fruits from time to time.
8. Install sex traps methyl eugenol (1ml/litre) + vinegar/gur (2-3 g) + malathion (1ml/l) -1 litre solution be made and traps be prepared by smearing the solution.
9. Application of carbofuran @ 200-300 g a.i./ha at sowing followed by 4 sprays of carbaryl 500 a a.i./ha at 10 day interval gave good control of beetle.
10. Spraying of dinocap 100 ml/750 litres water/ha gives good control of powdery mildew.

Onion

1. The sprinkling of water through jet nozzles to prevent thrips multiplication.
2. Yellow sticky traps for thrips etc.
3. Spray of NSKE 5% during vegetative growth for thrips. 2-3 sprays may be given.
4. Spray mancozeb @ 1.0-1.5 kg a.i/ha for leaf blight if serious problem.

Pea

1. Early varieties-Badger and Asauji are quite tolerant to stem fly attack as compared to Arkel. Even Bouniville, a very popular late variety, is tolerant to stem fly. However, leafminer is more serious in late sown crop like Bouniville but not causing economic damage (Singh and Misra, 1977).
2. Late sowing of pea i.e. in November month escapes the attack of stem fly even in Arkel variety.
3. Seed treatment with *T. viride* @ 4 g/kg of seed.
4. Application of carbofuran 3G @ 30 kg/ha in furrows below the seed checked the stem fly damage and leafminer damage and increased the yield as compared to untreated crop.

Source: Sardana and Sabir,2002

IDM Module for Diseases of Cauliflower

Stage	Operation	Target pests
Nursery sowing	Covered with nylon net (100m width).	Insect
Before transplanting	Seedlings dip in *T.harzianum* @ 4 ml/L. and carbendazim @ 0.05 g/L	Downy mildew, Alternaria leaf spot, stalk rot

Contd...

Stage	Operation	Target pests
Intercropping	Intercropping with onion seedlings	Stalk rot
After transplanting	Sprays as follows	
15 DAT	Bion@ 50mg/L	Downy mildew, Alternaria leaf spot, stalk rot
30 DAT	*T.harzianum* @ 4 ml /L.	
45 DAT	Ridomil @ 1 g/L	Downy mildew
50 DAT	ProKissan @ 1g/L	Downy mildew, Alternaria leaf spot, stalk rot
65 DAT	*T.harzianum* @ 4 ml/L.	Downy mildew, Alternaria leaf spot, stalk rot
75 DAT	Carbendazim @ 2 g/L	Alternaria leaf spot, stalk rot
90 DAT	Imidacloprid @ 0.08 ml/L.	Insect, virus
105 DAT	Agro Boom @2ml/L	Downy mildew, Alternaria leaf spot, stalk rot
115 DAT	Iprodione @ 2 g/L	Alternaria leaf spot

Source : Sharma *et al.* 2006

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8

GREEN HOUSE DISEASE MANAGEMENT

DISEASE MANAGEMENT IN GREENHOUSE SYSTEM

The commercial production of vegetables has become an important and innovative, money spinner technology throughout the world. In India, it has gained popularity very recently. Cropping system in greenhouses offers a particularly difficult challenge because the environment conditions for optimum crop production are often conducive to disease development and therefore, crop protection is the priority area . With the current restrictions in pesticide usage in greenhouses, cultural and biological methods are often alternatives for disease management. In the recent years, several new technologies, which offer more natural way of controlling pathogen, have been studied and proposed for commercial use. In general, commercial greenhouse operations aim at supplying high quality, high value products to specific markets. From a phytopathological point of view, the high labour, high technology inputs of the greenhouse industry provides unique opportunities for disease control, especially the avoidance of infection. On the other hand some disease which are of minor importance or even unknown in the field, may become a serious limiting factor in crops production in the greenhouse (Sharma, 2000).

Greenhouse production being the basis of high-value crop receives relatively intensive management. In many countries, crops are grown in heated glasshouses, mostly in rockwool or other soil-less media and the vegetable greenhouses are either not heated, or partially heated during the colder winter months. Moreover, restricted ventilation and low light intensity, especially on the lower plant parts, are common. As a result greenhouse atmosphere is saturated for long periods each day, and plant growth is affected. This situation is very conducive to several plant diseases and their control is very difficult. The most appropriate non-chemical method under greenhouse conditions would be the use of resistant cultivars. However, for the majority of the diseases there are no resistant cultivars available to growers. Farmers can practice manipulation of the greenhouse

environment to avoid water-dependent pathogens. However, the growers rely heavily on fungicides to protect their thrips. The high disease pressure and high crop value call for frequent applications of the most effective fungicides, which results in the selection and predominance of resistant pathogen strains in a rather short time. Hence, alternative control methods are urgently needed, either for conventional application or for integration with existing methods.

Plant Pathologists have been involved directly in the development and advancement of considerable number of natural products such as water-soluble silicon and plant extracts for disease control. Study of microbial ecology of pathogens and biocontrol organisms, disease escape phase and monitoring and controlling environment become important for the development of strategies for disease control in green houses. The use and development of biological agents, such as *Sporothrix flocculosa, Tilletiopsis spp.* and *Ampelomyces quisqualis* to control powdery mildew of greenhouse crops and sterilization of hydroponic solutions using different physical methods to prevent the introduction and spread of root and crown pathogens in closed re-circulating hydroponic solution system.

MICROBIAL ECOLOGY OF PATHOGENS

Fungi have specific and often different optimum environmental requirements for soprulation, dispersal, spore germination and infection. For example, consider the biology of ubiquitous gray mould pathogen, *Botrytis cineria* Pres. Fr. It is a necrotrophic pathogen whose inocula are enhanced from soliborne and debris borne sclerotia and largely saprophytic bases. It produces hygroscopic conidia at temperature above 12°C(best at about 15°C) in subsaturated atmosphere and releases them by hygroscopic mechanism in conditions of rapidly changing humidity, and generally infects plants especially wounded plants, from conidia occasionally ascospores in a film of water. Conidia germinate best at 20° C and germtube elongate fastest at 30°C. However, this fungus often infects plants directly from a saprophytically based inoculum such as fallen petal adhering to leaf or fruit surface. This behaviour has profound implications in the design of prophylactic disease escape and therapeutic control measures. Other group of fungi such as *Alternaria, Fusarium, Phytophthora, Pythium, Botrydiplodia and Verticillium* spp. and the downy mildew and powdery mildews each has its own set of ecological requirements that demand a different rationale in the design of environmental control measures.

Bacteria are also important pathogens of greenhouse crops, often of seedling such as tomatoes and situations where intensive plant handling and soil and water splash facilitate the transfer of inoculum. Bacterial diseases tend to be more serious in humid conditions; in succulent, soft plants; and in a certain areas of the greenhouse where such adverse conditions as poor drainage and roof drip occurs. The epidemiology of virus diseases depends largely on the mode of transmission; whether on pruning knives or fingers by insects. Thus in order to devise rational management control measures, for vital diseases the autecology of vectors become a subject for in-depth study. Understanding the autecology of phyllosphere biocontrol microorganisms is as important as understanding that of pathogens, if they are to be exploited rationally. The pycnidial hyperparasite of powdery mildew fungi, *Ampelomyces quisqualis Ces.* has sticky conidia that are splash dispersed, as are the spores of yeast like antagonist *Sporothrix* spp. They are both effective

in controlling *S. fulginia* on cucumber in high humidities. Biocontrol of powdery mildew therefore, depends on maintaining high humidities and occasional water sprays to ensure splash dispersal of antagonist spores. If a root pathogen regains early entry to sterilized medium, the medium becomes highly disease conducive because of the prior elimination of naturally occurring antagonists. Many antagonists, on the other hand, are retained in pasterusized and solarized media that thus generally remain suppressive to root pathogens. Enhancement of indigenous antagonist by means of ammendments such as chitin or composted hardwood bark or peat seems more effective.

DISEASE ESCAPE

Not withstanding a good standardization within greenhouse hygiene, long distance transport of inocula by air, water or machinery sometimes negates the elementary precautions. Once conditions for infection are recognized and their environmental parameters are defined, the infection can be prevented simply by avoiding those conditions. In case of fungi such as *B. cinerea,* which are dependent on waterfilm for spore germination and infection preventing temperature from reaching the dew point is an effective mechanism of disease escape. Primary function of any disease escape principle is of course, recognizing and eliminating inoculum sources, including contaminated or infected seed, diseased mother plant used for cutting weed reservoirs of viruses and insects vectors, trash piles, dirt on implements and heater house floors, and diseased mature crops in the same greenhouse as seedlings. By recognizing quiescent phase of pathogen, disease can be avoided. In quiescent phase of gray mould in tomato stems, conidia, of *B. cinerea* lie in clumps in xylem vessels of petiole stub at deleafed nodes for upto 12 weeks before germinating (Jarvis 1980). The aggressive state of pathogenesis can be delayed by not over irrigating the ground bed that seems to delay tissue senescence. Thus, although the plant may be infected, aggression can often be delayed by managing the crop so that field is little affected. A simple crop management practice can similarly often save plants as in case of *Pythium* root rot and *Fusarium* crown and root not of tomatoes, the diseases of cool and wet soils. Altered greenhouse and bench design can improve air movement, which not only reduces the risk of diseases but also induces ethylene stress and hardier plants. Bottom heat, means of avoiding *Pythium* and *Rhizoctonia* root rots, is enhanced in a seedling and cutting trays that provide for upward movement between the young plants.

MONITORING AND CONTROLLING THE ENVIRONMENT

Monitoring the environment and controlling it to keep plants disease free and pest free has become a fundamental part of greenhouse management. Once the environmental parameters for the various activities of pathogen and biocontrol organisms are understood, those activities can be regulated by the relatively precise control which grower can exercise over environment. Computer monitoring and controlling of temperature energy input and conservation can enhance precision. Light, shade, air movement and ventilation, water vapour density, relatived humidity, dew point, crop nutrition and carbon dioxide enrichment of these factors, manipulating the interaction of temperature and water vapour density is probably the most important in the control of disease of leaves, flowers and fruits. Rhizosphere moisture is the most important for root diseases. Foliar and stem diseases include gray mold (*Botrytis*), powdery mildew (*Erysiphe* spp.), early blight

(*Alternaria* spp.), soft rot (*Erwinia* spp.), and several other fungal and viral diseaes caused by *Xanthomonas, Fusarium* and *Psuedomonas.*

Greenhouse climates are warm, humid and wind-free – an ideal environment for the development of many foliar and stem diseases. For the majority of pathogenic fungi and bacteria, infection usually occurs when a film or drop of water on the plant surface persists. Unless temperature, humidity and ventilation are well regulated, this surface water can remain in the greenhouse until infection becomes assured.

Integrated disease management, therefore, is based on climate control for disease infection and optimum crop yield and quality. It eliminates inoculum through high standards of hygiene (sterilizing soil or using soilless media, obtaining disease-free planting material, chlorine bleach rinses of footwear & equipment, vegetative-free floors, etc.), cultural practices for limiting disease spread, biological and pesticidal control, and most important, when available, resistant germplasm.

INTEGRATED MANAGEMENT OF DISEASES IN GREENHOUSE CROPS

The above strategies suit to the present international concerns for reduced pesticide usage. The best possible utilization in terms of developing methodologies applied at various levels are mentioned below:

1. Use of natural products
2. Use of biological control measures
3. Sterilization of re-circulating hydroponic solution to prevent the introduction and spread of pathogen.
4. Development of Expert system.
5. Resistant Varieties

USE OF NATURAL PRODUCTS

Soluble silicon

Wagner (1940) was the first to report that Si Fertilization could decrease, in particular powdery mildew in cucumber plants and Adatia and Besford(1986) noted that plants grown in nutrient solution supplemented with silicon had dramatically less powdery mildew than those which did not receive any soluble Si in their nutrition. Si treatment reduces the area of cucumber covered with powdery mildew by upto 98% and optimum disease occurring when the concentration of SiO_2 in the nutrient were 100 ppm and higher. Currently, potassium silicate is available commercially in Europe and marketed for the greenhouse cucumber (Menzies & Belanger 1996). While actual numbers are not available, it is estimated that 60% of cucumber growers use the product on regular basis. The recommended concentration for cucumber is 50 ppm. The beneficial effects of soluble Si amendments are corroborated only by empirical observations. Most growers will claim to have reduced use of fungicide and improved yield increases in cucumber because of the addition of disease, but there is a report of a 10.2% increase in the number of tomato harvested because of its addition to the hydroponic solution (Voogt 1992). However, in general it is difficult to critically assess the economic benefits of using soluble silicon.

Plant Extracts

The concept that some plant product extracted from plants may possess pesticidal properties is of prime importance in greenhouse management under current pressure of reduced usage of synthetic chemicals. Plant extracts from the giant knot weed *Reynoutria sacchalineses F. Schmidt(Naai)* have been reported to reduce infection of powdery mildew in long English cucumber (*Herger et al.*, 1988). In addition to this, it controls powdery mildew of tomato, apple, begonia and powdery mildew of grapevine and rust of bean and cereals are prevented by such a treatment. First attempts to commercialize the plant extract in the form of wettable powder proved unsuccessful because of the complicated manipulations in the addition of product. A liquid formulation has been developed (Milsana : BASF, Germany) which apparently overcame that problem. Milsana applied at recommended dose of 2%(v/v) provided excellent control over powdery mildew of greenhouse cucumber without affecting yields (Dik & Van Der Stray, 1995). Through collaborations with *A. Schmitt* of the Biological Control Research Centre at Darmsted Germany, Milsana was tested for the first time in North America at the University of Laval. Preliminary trials on English cucumber have corroborated results obtained in the Netherlands. Treated plants were significantly less infected by powdery mildew and had high yields than controls or plants treated with benomyl. The mode of action of Milsana remains unclear although it is known that it does not have direct fungicidal properties. Kowalweski & Herger(1992) reported that several defense enzymes, such as peroxidases, polyphenoloxydases and phenylalanine ammonia-lyase was stimulated in plants as a result of treatment with Milsana.

USE OF RESISTANCE ELICITORS

Abiotic and biotic elicitors are being worked out for inducing resistance in plants. Synthetic elicitors *viz.* CGA 41396 and CGA 245704 have been observed for developing resistance against powdery mildew of roses (Sharma, 1999). The concept of disease tolerance i.e. less yield loss than expected for a given level of disease, becomes more pertinent at low disease pressures. Furthermore, resistance elicitors sometimes have yielded enhancing effects that are not attributable to disease control alone.

USE OF BIOLOGICAL CONTROL AGENTS TO CONTROL GREEN HOUSE DISEASES

Research has demonstrated the potential of biological approaches for control of plant diseases, but there are only a few commercialized systems for the biocontrol of plant diseases, especially those affecting the foliar parts (Elad, 1994; Elad & Chet, 1995). The most common greenhouse diseases caused by *Botrytis* and powdery mildews have been of interest towards which intensive biocontrol efforts have been directed and gained practical success. *Botrytis cinerea* causes severe loss in may fruit, vegetable and ornamental crops (Schwinn 1992) and which can be especially important in production (*Jarvis*, 1980). In greenhouse, flower crops such as rose and gerbera, small nectoric lesions are observed on petals. During severe epidemics the entire foliage may be destroyed. Stems of plants can be infected either by invasion of fungus through the petiole or by direct infection of wounds after pruning and harvesting. Such infection may entirely girdle the stem, kill the entire plant and cause substantial yield losses. The other groups of stem, kill the entire plant and cause substantial yield losses. The other groups of fungal pathogens are powdery mildews. *Sphaertheca fuliginea, Erysiphae cichoracearum, Oidium* sps. *Sphaerotheca*

pannosa var. *rosa, Leveilulla taurica,* damage flowers, vegetables and some of the greenhouse fruits (Table 1). The initial inoculums of powdery mildews consists mostly of conidia. Inoculum is easily transferred from greenhouse crops to the open field and vice versa. Powdery mildew conidia are self-sufficient in water and nutrients and, although infection, is favoured by low vapour pressure deficit, can be severely damaged when immersed in water onthe plant surface. Powdery mildews are characterized by grey to white sporulating colonies on the upper leaf surface; symptoms may also appear on lower surface and on stems and flowers in severe epidemics.

TABLE 1

Mechanisms of biological control successfully exploited in greenhouse crops

Mechanism of biocontrol	Disease	Biocontrol	Crop
Allelopathy	Fusarium crown and root rot	Lettuce dandelion residues	Tomato
Hyperparasitism	Powdery mildew rust	*Ampelomyces quisqualis* *Verticillium lecanii*	Cucumber, carnation
Antibiosis	Powdery mildew	*Tilletiopsis* spp. *Stephanascus* spp.	Cucumber
Suppressive soils	Fusarium wilt	*Streptomyces*	Carnation
Competitive sapropytic ability	Fusarium wilt	Saprophytic *Fusarium spp.*	Carnation Poinsettia
Soil amendments	Fusarium crown and root rot	Chitin, composted hard wood bark	Tomato Cucumber
Cross protection	Fusarium wilt, *Rhizoctoma* and *Pythium* root rot	Nonpathogenic *Fusarium oxysporium*	Tomato
Passive exclusion	Gray mold	*Cladosporium* spp.	Tomato
Hypovirulence	Tobacco mosaic virus (TMV)	Attenuated TMV	Tomato

Source: Jarvis (1989)

Trichoderma

Intensive biocontrol work with *Trichoderma* spp. under commercial conditions has been carried out on grey mold of grapes and some significant achievements on greenhouse crops. Isolate T 39 of *T. harzianum* selected in Israel, has effectively controlled Botrytis diseases in Israel (Elad, 1994). A commercial preparation developed from T 39 (Trichodex, 20P, Makhteshim Ltd. Be'er Sheva, Israel), registered for agricultural use in Israel and other countries, is the first product to be introduced commercially in greenhouse.

Ampelomyces quisqualis

The fungus *A. quisqualis* was first reported as a hyperparasite of powdery mildew

on Clover in 1932 (Yarwood, 1932). It has been shown to antagonise several members within the Erysiphaceae. It has been used as water spray in order to alleviate its need for high humidities. Phillipp *et. al.* (1990) demonstrated that *A. quisqualis* have acceptable control of cucumber powdery mildew in the field if applied with 2% paraffin oil. Ecogen company (Israel) has developed a formulation based on strain AQ10 that tolerates lower humidities.

***Tilletiopsis* spp.**

Several species belonging to genus *Tilleetiopsis* have been reported to have antagonistic properties against powdery mildew. *T. washingtonesis* and *T. pallescens* Gokhale, when applied at a range of 1×10^8 ml, could significantly reduce cucumber powdery mildew under green house conditions.

Sporothrix flocculosa

It is a yeast like, epiphytic fungi demonstrated to have powerful antagonists activity on cucumber, rose, begonias (Jarvis *et. al.* 1993) powdery mildews *S. flocculosa* was much less demanding than *Tilletiopsis* spp. in terms of humidity requirement to maintain its efficacy. Choudhary *et. al.* (1994) demonstrated that antibiosis was the main mode of action exerted by the antagonist which allowed for a fast control of the pathogen.

Sterilization of Recirculating Hydroponic solutions to prevent the introduction and spread of root pathogens

Sterilization is an effective way to decrease the spread of pathogen in recirculating hydroponic system. The pathogen includes species of *Phytophthora, Pythium, Fusarium, Phomospsis, Humicola, Olpidium* and associated viruses. Sterilization methods include.

Heat pasteurization

Treatment of recirculating hydroponic solutions with heat pasteurization at 95°C for 30 seconds has been found to be inactive on Tobacco mosaic virus and cucumber green mottle mosaic virus, and stop the spread of *Verticillium dahliae* Kleb, *Fusarium oxysporium* f.sp. *melonis, Olpidium* sp. and *Pythium aphanidermatum* (Runia, 1994). Heat pasteurization is strongly recommended technique for sterilization of recirculating hydroponic solutions.

Ultra violet light

Ultra violet light treatment of recirculating, solutions is effective against bacteria and fungi *Fusarium oxypsorium* and *Pythium aphanidermatum* (Runia, 1994), when the solution is treated with dose of 100 ml/cm^2 and effective against viruses (Runia, 1993). For commercial practice, a dose of 150 mg/cm^2 is recommended because the composition of drain water changes throughout the cultivation season and pathogen inoculum levels in the water are unknown.

Ozone

The recommended dose of ozone treatment of water is 10g/h for 1 m^3 to achieve a redox potential of 754 mV in the solution. This inactivates the cucumber green mottle mosaic (Runia, 1993) and stops the spread of *Phytopathora nicotianae, Verticillium alboatrum* and *Phythium aphanidermatum, F. oxysporium* f.spp. *melonis, F. oxysporium* f.sp. *lycopersici* (Runia, 1994).

Slow sand filtration

Slow sand filtration offers a cheap alternative to the other systems, but it has not been found to be as effective. Research has shown that *Phytophthora* sp. could be removed with sand filters (Menzies & Belanger, 1996). This system would be effective in a situation where *Phytophthora* and *Pythium* spp. were only pathogen concerned.

Iodine

This technique involves the passing of hydroponic solution over iodine laden resin, after which it is passed over a carbon filter to remove the iodine. Iodine is extremely phytotoxic when placed directly in the nutrient solutions. Nevertheless, this system is only in the experimental stage. It is found to be effective in the killing conidia of *F. oxysporium* f.sp. *lycopersici* at 0.7 ppm iodine or higher.

Hydrogen peroxide

Hydrogen peroxide acts in a same manner as ozone, in that it is an oxidizing agent, but it not as strong as ozone (Domingue, 1988). Tomato mosaic virus was inactivated at 400 ppm and conidia of *F. oxysporium* f.sp. *lycopersici* were killed at 100 ppm (Runia, 1993).

Development of an expert system

Green house managment comprises an interrelated order of factors, which are responsible for an efficient and productive system (Clark *et al.*, 1994). The various factors mentioned in Fig. 1 are self-explanatory. First order factors directly affects the greenhouse crop, second order factors directly affects the first order factors and indirectly the crop and so on. For example, diseases are directly influenced by the management practices, the environment, chemical pesticides, biological control agents, vectors and plant nutrition (Fig. 1). But these same factors affect the crop directly or indirectly. An expert system approach offers a solution to the problems of solving the complex and interrelated problems of green houses through knowledge of the complex strategies and manipulation of the environment. Several expert systems have been developed for greenhouse applications. Gohler (1989) described a simple conceptual model of an expert system that provided advice on a plant nutrition, temperature control and pest control for greenshouse cucumber Jarvis *et. al.*, 1993; Shipp *et al.*, 1993 have developed an expert system, which requires 386 personal computer and microsoft Windows for operation. The expert system can recognize and recommend 33 diseases, 22 physiological disorders and 15 pests of greenhouse cucumber.

Resistant varieties

Resistant varieties can be the major strategy of any greenhouse crop. Resistance can also be induced by one of abiotic and biotic elicitors which can be best exploited under controlled environment. (Varities referred in Chapter 6).

Managing the complex greenhouse cropping system requires a multidisciplinary approach that integrates pest and disease protection strategies with routine cultural practices and environmental and fertigation regimes into a common decision making process or integrated crop management strategy. The accessibility of information is a formidable problem in itself for the grower, but the greatest problem for the grower is the

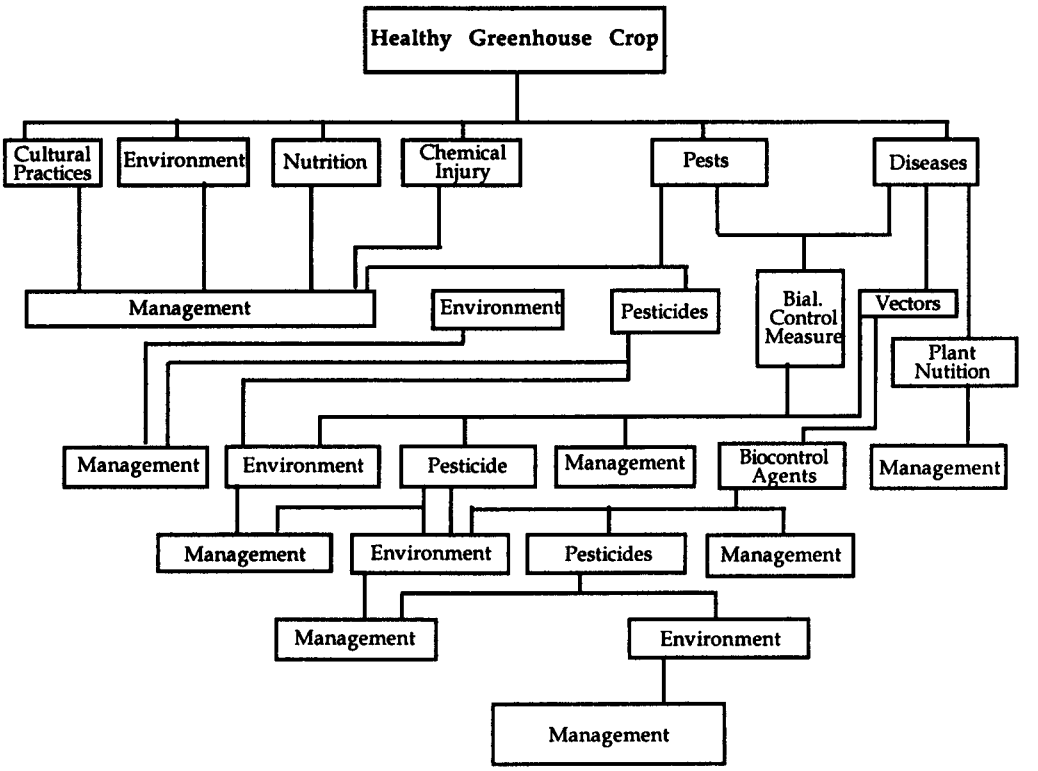

Figure 1 : Simplified hierarchy of factors affecting greenhouse plant production within an integrated crop production framework. Changes in any one factor can affect virtually all others.

right combinations of the various recommendations made by individual experts of different disciplines. A recommendation of biological control made by the pathologist can be inhibitory to the monitoring of environment for good production of the crop. Use of a fungicide may be harmful for any bio-pesticide. To develop grower friendly integrated management system, conflicts of expert knowledge in five key areas; crop production, crop disorder prevention, and disorder control should be resolved so as to plot the best and most profitable crop management strategy. Greenhouse crop management is still an art as a science. In this complex cropping system where a grower is not only required to manage the disease but also the complex environment. For any export venture there should be strong technology support base have to depend on the foreign collaborators who are not aware of Indian conditions disease and availability of suitable agro-chemicals. Many a time imported pesticides are not available and Biopesticides have not been identified for certain pests. Advance planning in plant protection measures will greatly facilitate quick control measures. We need to work effectively to develop suitable indigenous plant protection technologies, which are economical, grower friendly for the upcoming commercial ventures.

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9

DISEASE MANAGEMENT IN ORGANIC FARMING SYSTEM

Organic farming is a form of agriculture which avoids or largely excludes the use of synthetic fertilizers and pesticides, plant growth regulators, and livestock feed additives. As far as possible organic farmers rely on crop rotation, crop residues, animal manures and mechanical cultivation to maintain soil productivity and tilth, to supply plant nutrients, and to control weeds, insects and other pests.

According to the international organic farming organization IFOAM : *The role of organic agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings.*

Organic farming excludes the use of synthetic inputs, such as synthetic fertilizers and pesticides, and genetically modified organisms (GMOs). However organic farming regulations, as defined by the U.S.D.A, do not prohibit GMOs. In many countries the use of veterinary drugs is excluded. In a number of countries, including the US, Bulgaria, Iceland, Norway, Romania, Switzerland, Turkey, Australia, India, Japan, the Philippines, Korea, Taiwan, Thailand, Argentina, Costa Rica, Tunisia, and in the EU, organic farming is also defined by law, so that the commercial use of the term *organic* to describe farming and food products is regulated by the government. Where laws exist, organic certification is available to farms for a fee, and it is usually illegal for a non-certified farm to call itself or its products *organic*. Elsewhere, for example, in Canada, voluntary certification is available, while legislation may be pending.

Methods of organic farming vary. However, organic approaches share common goals and practices. In addition to the exclusion of synthetic agrichemicals, these include protection of the soil (from erosion, nutrient depletion, structural breakdown), promotion of biodiversity (e.g. growing a variety of crops rather than a single crop), and outdoor

grazing for livestock and poultry. Within this framework, individual farmers develop their own organic production systems, determined by factors such as climate, market conditions, and local agricultural regulations.

STATUS OF ORGANIC FARMING

INTERNATIONAL

The organic movement began as a reaction of insiders (agricultural scientists and farmers) against the industrialization of agriculture. Advances in biochemistry, (nitrogen fertilizer) and engineering (the internal combustion engine) in the early 20th century led to profound changes in farming. Research in plant breeding produced hybrid seeds. Fields grew in size and cropping became specialized to make efficient use of machinery and reap the benefits of the green revolution. Technological advances during World War II spurred on post-war innovation in all aspects of agriculture, resulting in such advances as large-scale irrigation, fertilization, and the use of pesticides. Ammonium nitrate, used in munitions, became an abundantly cheap source of nitrogen. DDT, originally developed by the military to control disease-carrying insects among troops, was applied to crops, launching the era of widespread pesticide use.

While some indigenous cultures had been farming organically for centuries, organic agriculture began to develop consciously in Central Europe and India in the early twentieth century as a reaction to industrialization. The British botanist, Sir Albert Howard often called "the father of modern organic agriculture" studied traditional farming practices in , India. He came to regard such practices as superior to modern agricultural science and recorded them in his 1940 book, *An Agricultural Testament.*

In Germany, Rudolf Steiner's *Spiritual Foundations for the Renewal of Agriculture,* published in 1924, led to the popularization of biodynamic agriculture.

The first use of the term *organic farming* is usually credited to Lord Northbourne, in his book, *Look to the Land* (1940), wherein he described a holistic, ecologically balanced approach to farming.

In the US, J.I. Rodale popularized organic gardening among consumers.

In 1972, the International Federation of Organic Agriculture Movements (IFOAM), was founded in Versailles, France. IFOAM was dedicated to the diffusion of information on the principles and practices of organic agriculture across national and linguistic boundaries.

In the 1980s, various farming and consumer groups worldwide began pressing for government regulation of organic production. This led to legislation and certification standards being enacted beginning in the 1990s.

Since the early 1990s, the retail market for organic farming in developed economies has grown about 20 per cent annually due to increasing consumer demand. While small independent producers and consumers initially drove the rise of organic farming, meanwhile as the volume and variety of "organic" products grows, production is increasingly large-scale.

INDIA

Organic farming system in India is not new and is being followed from ancient

time, the references are available in Bhav Prakash Granth and Atharvaveda. It is a method of farming system which primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials along with beneficial microbes (biofertilizers) to release nutrients to crops for increased sustainable production in an eco friendly pollution free environment.

As per the definition of the USDA study team on organic farming "*organic farming is a system which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives etc) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection*".

In another definition FAO suggested that "*Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs*".

With the increase in population our compulsion would be not only to stabilize agricultural production but to increase it further in sustainable manner. The scientists have realized that the 'Green Revolution' with high input use has reached a plateau and is now sustained with diminishing return of falling dividends. Thus, a natural balance needs to be maintained at all cost for existence of life and property. The obvious choice for that would be more relevant in the present era, when these agrochemicals which are produced from fossil fuel and are not renewable are diminishing in availability. It may also cost heavily on our foreign exchange in future.

Crop Protection in Organic Farming System

Crop Protection is the most important phenomenon in any crop production technology, because the crops (hosts) are the home of the pathogens. These pests are defined by us , but the all these microorganisms and microorganisms are the part of nature. We in the desperation of utilizing the crops feel they cause losses and therefore, pest and diseases always will be the with the crops. Pests and diseases do not generally cause significant disturbances in well established organic systems although certain specific problems do require remedial action. The healthy plant, given optimal soil condition and balanced nutrition, well be able to resist pests and pathogens better. A healthy plant is one which not only shows no disease symptoms but can also actively resist the onset of an infection.

The late French plant physiologist Chabousson,(1977 & 1985) few points summarised below :

- Healthy plants are able actively to resist pest and disease pathogens;
- This ability to resist attack is related directly to the synthesis of protein by the plant;
- Protein synthesis can be disturbed either by the direct effect of pesticides or by unbalanced crop nutrition resulting in excess uptake of certain nutrients and in some cases the suppression of others (this may also happen when environmental factors such as temperature and humidity are not optimum).

- When protein synthesis is disrupted, there is a build-up of water soluble sugars and nitrogen compounds as well as free amino acids in the plant tissue.
- These soluble compounds provided an ideal nutrient source for pathogens;
- Given these ideal nutrient conditions, pathogens are able to reproduce at a faster rate, even to the extent of out-growing the natural predators which would normally keep them in check.

The type and quantities of fertilizer used, both organic and inorganic, are as an important aspect of this. Nutrient imbalances can occur if readily available minerals fertilizers are used in significant quantities, either because of luxury uptake of nutrients such as nitrates which are subsequently stored in the plant cells until use can be made of them, or because the presence of high quantities of nutrients ions in the soil solutions blocks the release and uptake of other nutrients. In particular, the nitrate, ammonium and chloride ions have been shown to be harmful in this respect, with ammonium and chloride ions being directly toxic to young plants.

The effects of nutrients imbalances can also be seen in livestock, for example hypomagnesaemia, which is due to excess potassium and nitrogen uptake by grass at the expense of magnesium and is rarely, if ever, found on organic farms. Other minor or trace elements, such as sulphur, copper and boron may be lacking and lead to deficiency symptoms or diseases.

Crop protection system is influenced by following parameters:

Optimal site conditions (soil, climate, and environment)

Cultivations

Organic manuring and crop nutrition

Stalk and residue destruction

Soil moisture and irrigation

Diversity overtime

Discontinuity of monocultures

Crop rotations

Use of short- maturing varieties

Use of crop free or preferred host- free periods

Manipulation of sowing and harvesting dates

Diversity in space

Varietal mixtures

Resistant cultivators

Crop mixtures

Strip/ inter cropping (companion planting)

Mixed cropping

Under sowing

Soil cover

Management of wild plants (weeds) in and around crops

Altering pest behaviour

Use of trap crops

Use of manures, e.g. to stimulate hatching of nematodes at the wrong time

Size, planting density and shape of crops, e.g. use of scattered fields to create mosaic; spatial arrangement of plants

Pheromones

Biological controls

Augmentative releases of beneficial insects and pathogens.

PRINCIPLES OF ORGANIC PRODUCTION AT FARM LEVEL

Plant and Product Products:

1. The conversion period of at least two years before sowing or in the case of perennial crops other than grasslands at least three years before the first harvest. The conversion period of the whole holding varies depending upon the local conditions. Conversions is carried out under the supervision of representatives of the approved inspection agencies .Throughout the phase of conversion, all products be separately stored and clearly marked. Full records on inputs, crop yields and their use must be available. During the conversion period, the produce may only be sold as "in conversion" after the holding has been inspected; the production plan has been accepted and after a period of at least 12 months before the harvest has been completed with.
2. The fertility and biological activity of the soil must be maintained or increased where appropriate, by :

a. Cultivation of legumes , green manures or deep rooting plants in an appropriate multi - annual rotation programme.

b. Incorporation in the soil of Organic material, composted or not, from the holdings produced according to the rules of this regulation.

Other organic or mineral fertilizers as mentioned in Annex - I may be applied only to the extent that adequate nutrition of the crop are not possible by the methods described under (a) and (b) above.

For compost activation, appropriate micro- organism or plants based preparations may be used.

3. Pests, diseases and weeds shall be controlled by a combination of the following Measures,

- Choice of appropriate species or varieties
- Appropriate rotation programme,
- Mechanical cultivation procedures
- Encouraging natural enemies of pests
- Flame weeding.

Only in cases of immediate threat to the crop may recourse be had to products referred to in Annex—II.

ANNEXURE I

Permitted Materials for fertilization and Soil Conditioning

1. Organic materials

i. Farm yard and poultry manure after being properly composted.

ii. Slurry or urine, preferably after being aerated.

iii. Straw after being properly composted.

iv. Peat free from non- permitted materials.

v. Composts from spent mushroom and vermiculture substrates.

vi. Composts from biodynamic or organic household refuse.

vii. Composts from plant residues.

viii. Processed animal products from slaughter houses and the fish industries.

ix. Organic by- products of the food stuffs and textile industries, providing they are free from non- permitted materials.

x. Seaweed and seaweed products.

xi. Sawdust, bark and wood waste providing they come from untreated timber.

xii. Wood ash.

The use of animal resides (other than processed animal products from slaughter houses and the fish industries) from live- stock systems that do not comply with the provisions of Live Stock Production of EEC Standards are prohibited.

2. Mineral Fertilizers

i. Natural phosphate rock.

ii. Calcinated aluminium phosphate rock.

iii. Basic slag.

iv. Rock potash, provided it has a relatively low immediate solubility in water and low chlorine content.

v. Sulphate of potash.

Need must be recognized by Approved Body. Permitted only in case of known deficiency related to plant health.

vi. Limestone.

vii. Chalk

viii. Magenesium rock (including Kieserite).

ix. Calcareous magnesium rock.

x. Epsom salt (magnesium rock).

xi. Gypsum (calcium sulphate).

xii. Trace elements (boron, copper, iron, manganese, molybdenum, zinc).
Need must be recognized by approved body.

xiii. Stone meal.

xiv. Clay (bentonite, vermiculite, perlite including zeolites which are prohibited materials).

ANNEXURE II

Products for plant pest and diseases control

Preparations on basis of pyrethrins extracted from

Chrysanthemum cinerariaefolium, containing possibly

A synergist.

Preparations from *Derris elliptica*

Preparations from *Quassia amara*

Preparations from *Ryania speciosa*

Propolis

Diatomaceous earth

Stone meal

Preparations on basis of metaldehyde containing a repellent to higher animal species

And as far as applied within traps

Sulphur

Bordeaux mixture

Burgundy mixture

Sodium bicarbonate

Potassium soap (soap soft)

Pheromone preparations

Granulose virus preparations

Plant and animal oils

Paraffin oil.

DISEASE MANAGEMENT

Plant diseases cause challenging problems in commercial agriculture and pose real economic threats to both conventional and organic farming systems. Plant pathogens are difficult to manage for several reasons. First of all, plant pathogen is hard to identify because they are so small. The positive identification of pathogen often requires specialized equipment and training, and in some cases accurate diagnosis in the field is difficult.

Plant pathogen are constantly changing and mutating, resulting in new strains and new challenges to growers. Also, given the local, regional, and international movement of seeds, plant material, and farming equipment, new and introduced pathogens periodically enter the cropping system to cause new disease problems.

Disease management is complicated by the presence of multiple types of pathogens. For any one crop the grower must deal with a variety of fungi, bacteria, viruses, and nematodes. This situation is even more complicated for organic vegetable crops and is prohibited from applying conventional synthetic fungicides. The world market continues

to be extremely competitive and continues to require that growers supply high- quality, disease- free produce with an acceptable shelf. Disease management is therefore a critical consideration in organic vegetable production.

In an organic system, it is appropriate to develop disease-control strategies that have an ecological basis. For example, insofar as possible the organic system should encourage the growth and diversity of soil-inhabiting and epiphytic (plant surface dwelling) microorganisms that have the potential to exert beneficial and the pathogen- antagonistic influences. An increase in the genetic diversity of the crop host rotation is another management step that incorporates ecological considerations.

Plant disease control measures are aimed at reducing or eliminating one of the three factors involved in disease development: an infectious pathogen, a susceptible host and a suitable environment. Not only do these factors interact, but disease control strategies also must be woven together with management methods to address weed, insect and other production concerns. In a The long term field experiment for seven years at Jhalandhar (Sharma *et al*. 1988) revealed that FYM was more effective in increasing tuber yield than green manuring with dhaincha. Grewal and Jaiswal(1990), reported that the yield increase was due to increase by increasing organic matter. From studies in different places, it was found that FYM to supply 100 kg $P_2O_{5/ha}$ (about 30 t/ha) not only met P and K needs of the crop but also kept the potato yield level at a higher level that the combined use of P and K fertilizers (Sud and Grewal, 1990).Role of green manures in economising P and K for potato has been evaluated in the field experiments at Jalandhar (Sharma et.al. 1988, Sharma and Sharma, 1990) **Tomato**:- Application of oil cakes of margosa, castor and groundnut (at the rate of 0.2% (WW) is generally found to reduce the intensity of root gall development. Chinnaswamy (1967) found best results with FYM and groundnut cake in organic mixture. Thamburaj (1994) found that organically grown plants were taller with more number of branches. They yielded 28.18 t/ha which was on par with the recommended dose of FYM and NPK (120:100:100 kg/ha).**Brinjal, Okra and Cauliflower**:- Highest yield of brinjal was with 50kg N/ha as poultry manure and 50 kg N/ha in the form of urea (Jose et al. 1988) while Okra responded to poultry manure at 20 Kg N per ha. (Abusaleha and Shanmugavelu, 1989). Singh and Mishra (1975) obtained highest returns of cauliflower by mulching with mango leaves. **Garlic**:- Singh and Tiwari (1968) found good garlic yield by applying 50 kg N/ha through organic

There has been considerable interest in the use of baking soda (sodium bicarbonate, $NaHCO_3$) and potassium bicarbonate ($KHCO_3$) to control powdery mildew and other fungal diseases of plants.The use of baking soda as a fungicide is not a new idea. In Alfred C. Hottes' *A Little Book of Climbing Plants*, published in 1933 by the A.T. De La Mare Co. of New York, mention is made of using one ounce of baking soda per gallon of water to control powdery mildew (PM) on climbing roses. The author credits the idea to a Russian plant pathologist, A. de Yaczenski. (Williams and Williams 1993)

The reported powdery mildew control property of foliar spray of sodium bicarbonate or baking soda has generated a lot of interest among certain grower group. If effective, it would be very attractive to grower because it would be consumer and environmentally friendly, inexpensive and as a food item, would probably not have rigorous registration requirement. Homma et al (1981) reported that foliar application of sodium bicarbonate

at concentration of 2.000 ppm had an inhibitory effect on *S.fuliginea* on cucumber and *L.taurica* on pepper. Inhibitory effect of the sodium bicarbonate was further enhanced if an anionic surfactant was added to the spray at a concentration of 0.41% since this initial report, foliar spray of sodium bicarbonate have been reported to control *Sphaerotheca pannopsa* var. *rosae* on rose (Horst et al 1992) *Oidium euonymai-japonica* on *Euenymes japonica* (Ziv and Hagliadi 1993), and again *S.fuliginea* (As well as other disease) on cucumber (Ziv and Zitter 1992) with the control being protective in nature (Ziv and Hagliadi 1993, Ziv and Zitter 1992) The effective concentration of sodium bicarbonate in these study range from 1-2% and in the later study the favored surfactant use was sun spray ultra fine oil at 1% (v/v;Horst et al 1992, Ziv and Hagliadi 1993, Ziv and Zitter 1992) and inhibitory effect lasted 10-14 days after treatment.

Sun spray ultra fine oil was found to have an inhibitory effect on its own in two of the studies, but the combination of the oil with sodium bicarbonate was more effective than either product on its own (Horst *et al.* 1992) also examine the effect of potassium bicarbonate and ammonium bicarbonate on powdery mildews and found that potassium bicarbonate also was effective in reducing the severalty of powdery mildew on *E.japonica* and pumpkin but not ammonium bicarbonate. Some phytotoxicity was noted for sodium bicarbonate at concentration greater than 1% on rose (Horst *et al.* 1992) and for potassium bicarbonate at concentration greater than 0.5% on pumpkin.

In the August, 1985 issue of *Organic Gardening* magazine, a short article by Warren Shultz entitled "Recipe for Resistance" reports that researchers in Japan obtained effective control of PM on cucumbers, eggplants, and strawberries. They suggested weekly sprays of ¼ ounce baking soda per gallon of water.(Williams and Williams 1985)

Some of the work at Cornell has focused on controlling fungal diseases on cucurbits.(Williams and Williams 1992) A single spray application (to runoff) of 0.5% (wt./vol. of water) baking soda, plus 0.5% (vol./vol. of water) SunSpray UFP® horticultural oil almost completely inhibited PM on heavily infected pumpkin foliage. Baking soda without spray oil was ineffective, and a 2% (wt./vol. of water) solution of baking soda damaged the leaves. Baking soda/oil sprays also provided good control of *urocladium* leaf spot in cucumber, Alternaria leaf blight in muskmelon, and gummy stem blight in muskmelon.(Williams and Williams 1992) Other diseases against which baking soda may prove effective include anthracnose in cucurbits (Hofstetter1993); rust, dollar spot, and Pythium blight in turf; late blight in potato; rust in wheat; and diseases affecting other crops.

The Federal EPA ruled (as of December, 1996) that sodium and potassium bicarbonates are exempt from residue tolerances. This action served to facilitate the development and release of commercial bicarbonate products for horticultural use. It also lent weight to the belief that these materials are largely innocuous from a food safety perspective.

Various carbonates and bicarbonates have been proven effective against gray mold, an important post-harvest disease of grapes. Researchers found that carbonates were more effective than bicarbonates at reducing gray mold *(Botrytis cinerea)* spore germination, and that sodium and ammonium bicarbonates were better than potassium bicarbonate. (Anon 1998).

SOME IMPORTANT TIPS FOR ORGANIC FARMING GROWERS

Plant pathogens are microscopic, but they can cause big problems, from rotting fruit to wilting and dying plants. Disease management is all about prevention – it's easier to stop a disease from getting started than it is to manage it once it starts spreading.

(1) Diseases development is based on three important components- a susceptible host, the presence of an infectious agent (a pathogen), and the right environmental conditions. Practices aimed at preventing crop diseases usually focus one of these components but if all three components well understood can bring a scientific management.

Disease-prevention practices are much the same for conventional and organic growers. The main difference is in the menu of materials that can be applied to crops to protect against disease. And, since organic farmers are supposed to use organic pesticides as a last resort, they need to do a really good job with preventative cultural practices.

Beware of Susceptible Varieties

Growing varieties that are resistant or tolerant to plant disease is one way to avoid problems. Resistant varieties suppress the activity of a pathogen so there are few if any disease symptoms. Tolerant varieties endure a disease without significant losses in quality or yield although they may exhibit disease symptoms.

Obviously, resistant or tolerant varieties are not available for all diseases on all crops. But it makes sense to plant varieties that can handle at least one or two of the pathogens a crop is likely to encounter in your area. If you've had trouble before with a specific disease, by all means seek out resistant varieties to trial on a small scale to determine if they meet your market needs and are suitable for your farm's growing conditions.

Sanitization

It pays to keep pathogens off your field, or to stop them from spreading to new fields or greenhouses if they are already present. There are many ways to exclude pathogens from your production system. First, try to keep out any materials that are already diseased or that might harbor inoculum that can cause infection.

Since many diseases can be seedborne, clean seed is a must. Not all diseases can be tested for, but when available, be sure to purchase seed that has been certified to be disease-free, or close to it. It's not really possible to assure that an entire seed lot is absolutely free of pathogens, but certified seed gives assurance that the risk posed by a seedborne pathogen is low.

Whether you buy transplants grow your own, inspect them frequently to make sure they are as free of visible disease symptoms before they go in the field. If a disease starts to show up, it may make sense to treat seedlings while they are still in the greenhouse instead of waiting until they are in the field and the problem gets worse.

When producing transplants, all materials should be as free of pathogens as possible. Use new pots and trays, or reuse them only if they are thoroughly cleaned with steam, bleach, or other disinfectants. Soilless potting mix can prevent introduction of soilborne pathogens into the greenhouse, but recycling old potting mix can negate that benefit.

Moving soil around on the farm is a good way to spread disease. Take steps to limit outside soil from entering the greenhouse on shoes, wind and equipment. Even a small amount of soil adhering to tractors or implements can spread soilborne pathogens from infested fields into clean fields. It's a good idea to power-wash equipment when moving between fields, especially those that are separated by significant distance.

Water can also harbor pathogens. Water that drains from fields should be diverted away from greenhouses and irrigation ponds. Recycling water in the greenhouse can spread diseases, especially bacterial infections, so scout frequently for problems.

Removal, or rouging, of infected plants can help slow or prevent the spread of disease, particularly if it's only on a few plants. With some diseases like Phytophthora blight on tomato, pepper or squash, incorporating infected rows or entire fields of plants is recommended to minimize further spread.

At the end of the season, sanitation is still important. Turn under old plants and crop residues immediately after harvest to slow the development of disease and limit the potential for over-wintering of inoculum.

Healthy Soil

By selecting or manipulating environmental conditions, it is possible to limit or prevent plant disease. A site that has well-drained soil reduces the risk of soil-dwelling diseases that require standing water to spread from plant to plant. Using wide row spacing can enhance air movement, which promotes faster drying and thus slows the development of some foliar diseases

Building healthy soils that contain an abundance of beneficial organisms is another tactic to keep disease in check. Fertile soil also helps plants avoid nutrient deficiencies that can cause stress and make them more prone to infection. In some cases excess fertility can cause a problem. For example, too much nitrogen may result in excessive, succulent leaf growth that is more susceptible to disease.

Adding compost to soil can benefit fertility and tilth, and it may also benefit disease management in some cases. Because compost is such a variable material, it is difficult to give specific recommendations about how, or if, it will suppress disease. In general, it appears that well-made, mature composts are most desirable for this purpose.

When preparing fields, tillage should reduce plant residues left from previous crops. Raised beds and/or subsoiling should be used to address drainage problems. Seed and seedlings should be planted at the proper depth and provided with adequate moisture to promote rapid emergence and establishment.

As the crop grows, irrigation management is very important to disease control. Regardless of the system you use, the goal should be to satisfy the water needs of your crops without putting on excess water that can encourage pathogenic fungi in the soil. For preventing most foliar diseases, drip irrigation is preferable to overhead sprinkler irrigation because it does not wet the foliage and promote disease development. When using overhead irrigation try to time the application of water so foliage can dry rapidly.

Crop rotation is perhaps the most important cultural practice for disease management, but it may also be the most complicated. It's not always clear exactly what crops should

be rotated for how long a period of time in order to suppress a disease. And besides that, growers still have to meet their market demands and plans for efficient use of equipment and labor. However, it is clear that crop rotation helps keep many diseases from building up over time - and that keeps bad things from happening.

A good rotation plan moves crop families around and alternates cover crops with cash crops. Some growers have a systematic rotation plan, and for others rotation is a seat-of-the-pants affair, guided by current conditions and past experience. Regardless of how you make rotation decisions, keep good records to help with your future planning.

Use Organic Sprays

If you have reason to expect a disease to appear, as when late blight is in the neighborhood, or if scouting turns up the first signs of a disease like powdery mildew, then it may be necessary to apply a protectant material to prevent crop loss.

Quite a few copper and sulfur-based fungicides are allowed for organic use, and they are relatively inexpensive and pose minimal environmental risk. Copper fungicides have some activity against a wide range of fungi and bacteria, but their effectiveness is limited, and under high disease pressure probably will not provide excellent control. Sulfur products also provide some control of many pathogens, but they usually are excellent for managing only some diseases such as powdery mildew. Both copper and sulfur can burn sensitive crops.

Organically-approved bicarbonate fungicides have recently become available. Bicarbonates have demonstrated good activity against powdery mildew and a few other diseases. Peroxide-type materials are also available for general suppression of diseases on plant surfaces.

Other organic options for disease suppression are products that contain microbes or their by-products, including species of *Trichoderma, Aspergillus niger, Bacillus,* and other beneficial organisms. For the best results possible with these materials, proper application and timing are essential. Most materials do not perform well if the disease is established, so applications should be made prior to infection.

Understand Mode of Disease Development

Whatever kind of farming you do, it helps to know what diseases you're up against. Some diseases are easy to identify, since they have tell-tale symptoms: concentric rings of dead tissue are characteristic of early blight on tomato and potato, for example. But positive identification of most plant diseases requires help from a university or commercial laboratory with specialized equipment and trained personnel. A key step toward effective disease management is sending samples to such a lab at the very first sign of disease symptoms.

When you identify a disease problem on the farm, be sure to put it in your records. That way, a few years down the road, you'll still know exactly which field to avoid with susceptible crops.

COMPOSTS FOR DISEASE SUPPRESSION

Incorporation of composts into soils is a fundamental cultural practice in organic production. Compost benefits the soil's fertility and condition in a number of ways, and also

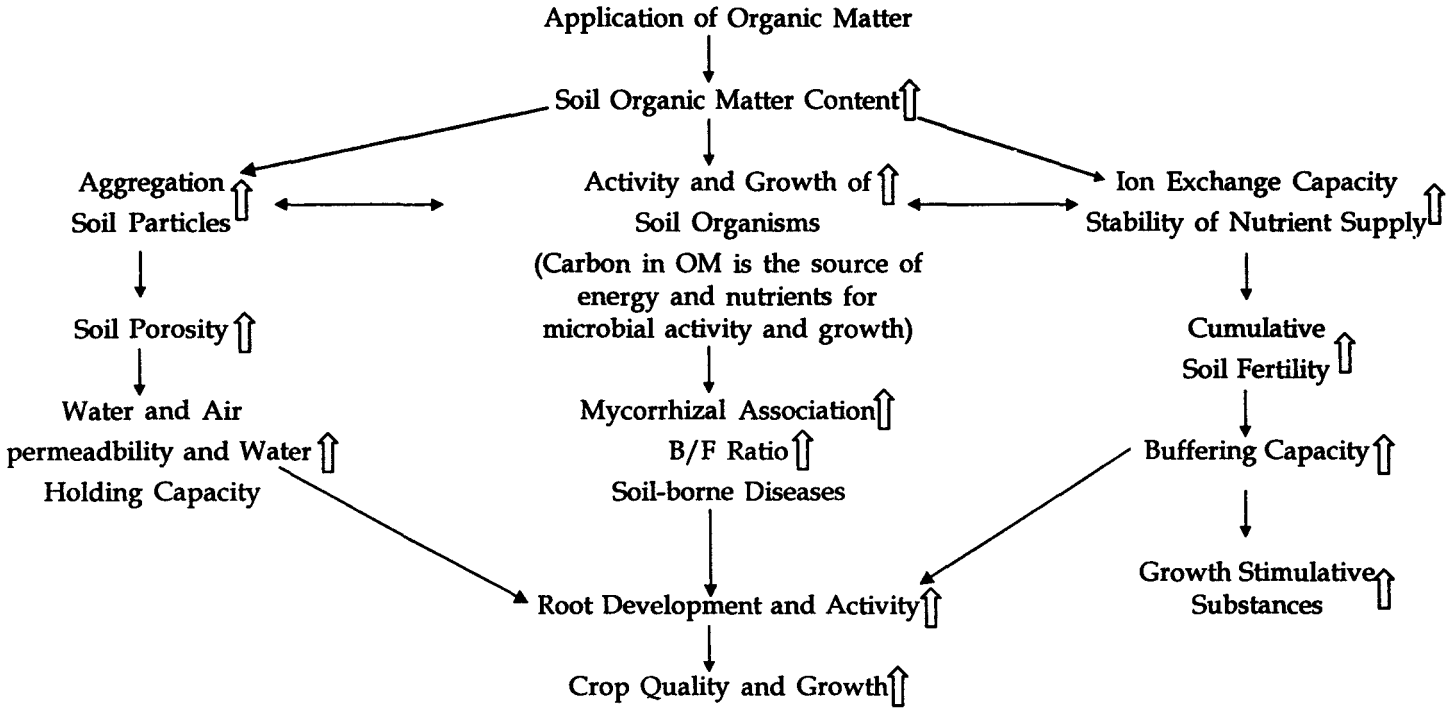
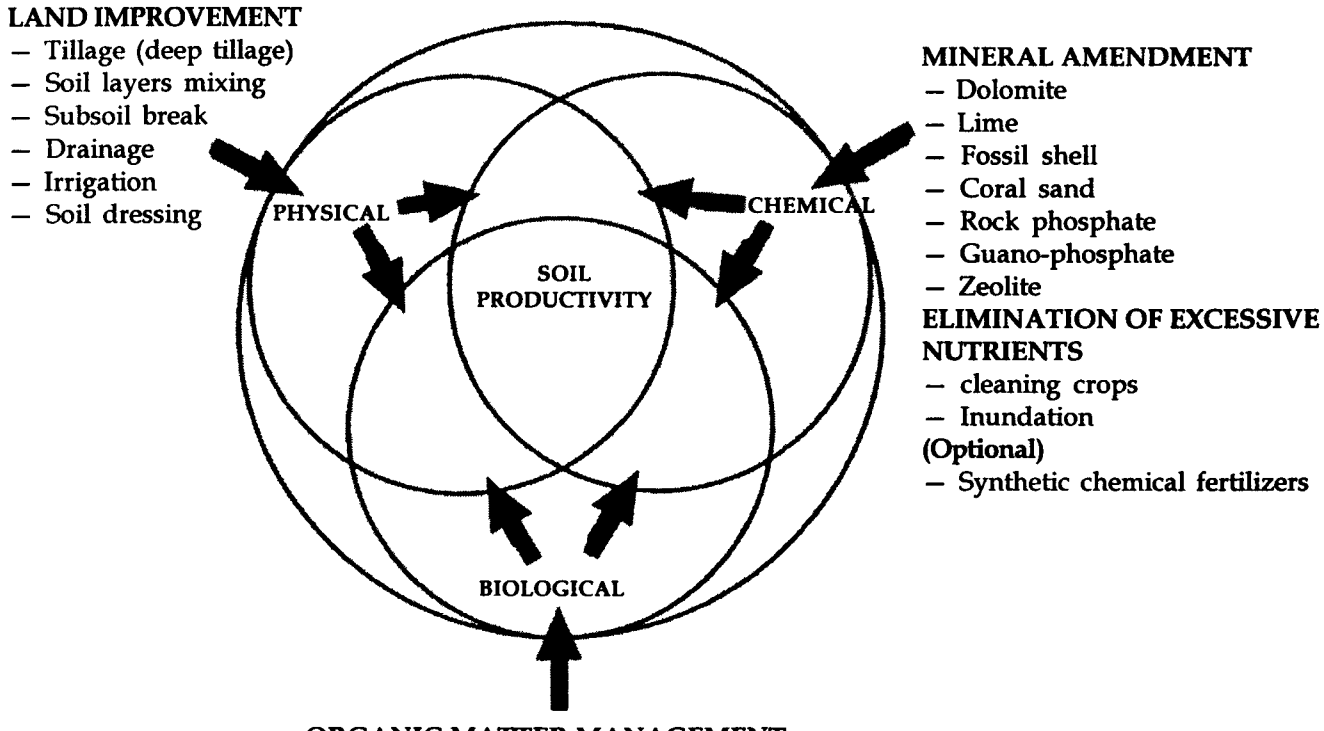


Figure 1 : Changes in soil properties induced by organic matter management



Source : Shoji Mizuno (1996) Organic Farming and Sustainable Agriculture Proceedings of the National Seminar held at UAS, Bangalore, India Oct. 9-11, Eds (Veeresh et al.) Ravi Publication(R), Bangalore.

Figure 2 : Fundamental practices of soil building

undoubtedly benefit disease management in some way. However, research studies and empirical data that clearly document any disease control benefits resulting form fieldapplication of compost are lacking. Despite this lack of information on disease control, composts should be added to farmed soils in order to increase soil microflora diversity and populations.

Composts have long been known to improve soil fertility and suppress plant diseases. More recently, it has been shown that components of composts improve the ability of plants to resist disease caused by root and foliar pathogens. Foliar and fruit diseases, especially early blight, septoria leaf blight, anthracnose, bacterial spot and speck, and bacterial canker can severely reduce yield and quality of fresh market and processing tomatoes. Extensive use of fungicides is often required to manage the diseases caused by fungi. Although the disease warning system TOM-CAST is available and has been shown to reduce the use of fungicides by 50% or more, it does not benefit organic farmers due to its reliance on synthetic fungicides. Further, it is not useful for control of bacterial diseases. Additional disease management strategies must be developed to further reduce fungicide use in conventional systems and to reduce diseases and subsequent economic losses in both conventional and organic tomato production systems.

The effect of composts on disease development in organic and conventionallyproduced processing tomatoes since 1996. Composts were obtained from commercial outlets (yard waste compost), produced at OARDC (composted cow manure) and produced in windrows by an organic farmer-cooperator (composted cannery waste, made from tomato cannery wastes, duck manure, municipal yard waste and reed canary grass straw). In field trials utilizing composted tomato cannery wastes, organic tomato yields were increased 27% and 42% in 1997 and 1998, respectively, for plants grown in compost-amended soil. Low rates of compost (10-12 tons/A) were as effective as high rates (20-24 tons/A). Anthracnose was significantly less in tomato fruit in compost-amended plots than in non-amended controls in 1998, a year in which the disease was very serious. Yield and quality improvements for plants grown in compostamended plots resulted in an economic gain of approximately $300 per acre.

In conventionally produced tomatoes, composted yard wastes hastened maturity of tomatoes by at least three weeks. Bacterial spot was reduced in 1997, a year with high bacterial disease pressure, in compost amended plots compared to non-amended control plots. The incidence of anthracnose on tomato fruit was not affected by compost amendments. However, the plant activator Actigard® reduced bacterial spot incidence in both years, and plants treated with Actigard® produced fewer fruit infected with anthracnose than control plants in 1997 but not 1998. Marketable yield in 1997 was higher in Actigard®-treated plots than in the control in 1997, reflecting the reduced incidence of disease. Yield was not significantly higher in compost-amended plots compared to the control.

These results indicate that compost amendments play a valuable role in reducing disease and increasing yields in organic tomato production systems, although not in conventional systems. It is possible that organic soils may better support a microbial community playing a role in induced resistance. Nutrients provided by composts play a greater role here also. Nonetheless, bacterial disease was reduced significantly in

compost-amended plots in the conventional system, so it is likely that induced resistance is also occurring at some level in this conventional soil. Early ripening of tomatoes in compostamended soils may provide an economic advantage for processing tomatoes and potentially for fresh market tomato production. Clearly, compost amendments should continue to be studied as a means of increasing sustainability in tomato production.

Soil-borne root diseases are generally less severe on organic farms than conventional farms, while there have been no consistent differences in foliar diseases between the two systems. The successful control of root diseases in organic systems is likely to be related to the use of long and diverse crop rotations, crop mixtures and regular application of organic amendments. Increased levels of soil microbial activity leading to increased competition and antagonism in the rhizosphere, the presence of beneficial root-colonizing bacteria and increased levels of vesiculararbuscular mycorrhizal colonization of roots have all been identified as contributing factors; in the control of root diseases. This is an unexplored area where native organisms play an important role for disease protection.

CULTURAL PRACTICES

There are a number of cultural practices that a grower should consider when designing an integrated disease control system. As a general approach, grower should take steps to grow vigorous, high quality plants using the best farming practices possible. Listed below are some specific cultural practices that can help to manage diseases.

Crop rotation is an important Consideration in disease management. Rotation using diverse crops, inclusion of cover crops and appropriate use of fallow(host free) periods all can contribute to the reduction of inoculums levels for soil borne pathogens and the increase of diversity in soil microfela. In contrast consecutive plantings of the same crop in the same field often lead to increase in soil borne pathogens. Too little crop rotation in a given area can also stimulate a monoculture effect that might increase foliar diseases. Recent research has shown that certain plants, besides being revenue generating crops, so have a suppressive effect on diseases. For example, after broccoli and other crucifer crops are harvested and the plant residue is plowed into the soil the decomposition of the broccoli stems and leaves releases natural chemicals that can significantly reduce the numbers of *Verticillium dahliae* microsclerotia. This broccoli can be an important consideration in crop rotation strategies. Some cover crops (mustards,sudangrass) might also share this beneficial effect and could be considered in the crop rotation scheme. It is important to remember that while rotation with non susceptible plants and cover crops may help reduce soilborne pathogen numbers, significant decreases in such populations are likely to take many reasons.

When devising a crop rotation strategy, a grower should also be aware of which crops and cover crops might increase disease problems. A vetch cover crop, if planted into a field with a history of lettuce drop, can greatly increase the infective sclerotia of *Sclerotiu monir.* vetch is known host a root knot nematode(Meloidogyne species) and also might increase soil populations of *Pythium and Rhizoctonia* (damping of fungi). While oil seed reddish could be potential trap crop for cyst nematode *(Heterodera* species), as a cover crop it is a host of root-knot nematode and the clubroot *fungus(Plasmodiophoru* brassicae).

There are many factors to consider in regard to planting a crop. Timing can be an important question. If cauliflower is planted into *Verticillium-infested* fields in the spring or summer, it is likely to experience disease and possible crop loss. However, if Cauliflower is planted into the same fields in the late fall or winter it will exhibit no Verticillium wilt symptoms, presumably because the soil temperatures are too cool to allow the fungus to develop and cause significant disease.

Disease can also be influenced by steps taken prior to and during the planting process. Tillage procedures should reduce plant residues left from previous crops. Proper preparation of the field and subsequent raised beds should reduce problems in areas that are subject to poor drainage, pooling of water, and other conditions that favor pathogens. Soil and bed preparation should result in good soil tilth so that seed or transplants are placed in a soil that favors plant development. Poor soil preparation can result in stressed and exposed plants and increased damping off problems due to soil fungi.

Irrigation management is clear and important factor when it comes to disease control. Regardless of the irrigation method a grower chooses(furrow, sprinkler or drip), timing and duration of irrigations should satisfy crop water requirements without allowing for excess water. Over watering greatly favors most soilborne pathogenic fungi. For most foliar diseases, overhead sprinkler irrigation enhances pathogen survival and dispersal and disease development. Bacterial fioliar diseases are particularly dependent upon rain and sprinkler irrigation. A grower should consider limiting or eliminating sprinkler irrigation if foliar diseases are problematic for a specific crop or field.

The selection and application of fertilizers, in a few documented situations can significantly influence disease development. For example, the use of nitrate form of nitrogenous fertilizers can increase the severity of lettuce corky root disease. The excessive use of nitrogen fertilizers can result in leaf growth that is overly succulent and more susceptible to some diseases. On the other hand, liming the soil to raise pHlevels can reduce symptom expression of club root disease of crucifers. In general, however, fertilizer management is not directly related to disease control.

Field sanitation is the removal or destruction of diseased plant residues. In some field situations, sanitation is an appropriate step for managing diseases. Once lettuce has been harvested, for example, the remaining plant can act as a reservoir for lettuce mosaic virus. Sanitation in this case would include plowing down the old plants. Lettuce drop, caused by the fungus *sclerolinicr minor,* occurs when sclerotia develop on lettuce plant residues and remain in the top few inches of soil. One form of sanitation involves deep plowing in which mold board plows invert the soil and bury sclerotia. Note that this procedure is effective only if sclerotia are low to moderate in number.

Sanitation measures are commonly applied in green house situations. The removal or dead or dying transplants can help reduce inoculums that could otherwise spread to adjacent transplants. The removal of senescent tomato or cucumber plants might reduce (though not prevent). The spread of *Botrytis* spores. *Roguing* is a special form ofplant sanitation the involves the physical removal of diseased plants form the field. while not applicable in many situations, researchers have shown that for sclerotiaforming fungi(such as *Sclervtiniu minor* on lettuce) the regular removal disease plants can gradually reduce the over all number of sclerotia in fields.

The managements of other pests is a cultural control that could greatly influence the development of plant diseases. In particular, virus disease management is more effective when weeds and insects are also controlled. Weeds are known reservoirs or a number of bacterial pathogens.

Soil solarizution is the use of plastic traps plays on the soil surface to increase soil temperatures to a level that kills soilborne pathogens, weeds, and other crop pests. Soil solarization works best in areas with acceptably high summer temperatures.. Soil solarization will not eradicate a pathogen from a field, but it may lower pathogen populations. Soil flooding is a related though seldom-used means of creating conditions – in this case, saturated soil over an extended period-that might result in a decline of soilborne pathogens.

Finally the ability tc manipulate environmental conditions in a greenhouse vegetable transplant or production system can be used to help control diseases. Botrytis disease can be better managed if warm, humid air is vented out of the green house. Because rain is not a factor in greenhouses, many bacterial foliar diseases can be virtually eliminated if drip irrigation or sub-irrigation systems are used.

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