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REVIEW ARTICLE

Global Scenario of Vegetable Fungal Diseases

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Abstract

Plant diseases threaten crop production and are responsible for considerable losses in vegetables worldwide. Every year diseases cause losses up to 40 to 60% in vegetable crops. Vegetable crops are comparatively more susceptible to various types of diseases inflicted by fungi, bacteria, virus, viroid, phytoplasma and nematodes. Genera of fungal pathogens viz. *Alternaria*, *Aschochyta, Colletotrichum, Didymella, Phoma, Phytophthora, Pythium, Rhizoctonia, Sclerotinia* and *Sclerotium* on vegetable crops increased tremendously. Emerging seed-borne and seed-transmitted fungal plant diseases became a major threat for the vegetable seed production system. Emerging diseases in vegetable crops like tomato (early and late blight, *Fusarium* wilt), chili and peppers (anthracnose, *Phytophthora* blight), brinjal (phomopsis blight, *Alternaria* leaf spot), cucurbits (Downey mildew, gummy stem blight, *Fusarium* wilt, fruit rot, anthracnose and *Cercospora* leaf spot), okra (*Cercospora* leaf spot), pea (powdery mildew, fusarium wilt, rust and root rot), French bean (*Sclerotinia* stem rot), cowpea/dolichos bean (anthracnose, *Sclerotinia* stem rot), cole crop (black rot, *Alternaria* blight, downy mildew) etc. The vegetable produce is spoiled by post-harvest pathogens and makes them unfit for human consumption and market due to the production of mycotoxins. Profiling, detection and diagnosis of vegetable pathogens (diseases) are essential for better understanding of pathogens and formulation of safe disease management strategy of vegetable crops. Therefore, there is an urgent need to wide array of diagnoses of pathogens of vegetables and their *in-vitro* testing towards chemo-sensitivity for formulation of safe management of vegetable diseases.

Keywords: Vegetable diseases, plant pathogens, diseases management, seed borne pathogens, soil-borne diseases, biological control.

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Introduction

India is the second largest producer of vegetables in the world with production of 200.45 million tonnes from an area of 10.86 million ha with productivity of 18.46 tonnes/ha. India is the second largest producer of vegetables in the world and accounts for 16% of global vegetable production (Tripathi *et al*., 2020; 2019). Diseases and their insect vectors are the major threats to vegetable production in the world. Achieving a 'zero hunger' world by 2030 depends on doubling of agricultural productivity and reduction of crop losses due to plant diseases. If we could alleviate the losses due to plant diseases, we would be able to produce roughly 20% more food enough to feed the predicted world population 9.1 billion by 2050 (Maxmen, 2013). As per estimates yearly, 20 to 40% crop losses caused by pests and diseases (Thind 2011, Dean *et al*. 2012, Savary *et al*. 2019, Singh *et al*. 2016, Tripathi 2021). Pests and diseases cause regional and seasonal losses (40–60%) in vegetable crops under field (15–20%), packaging and storage (15–20%) and transport (30–40%). Additionally, sometimes 100% yield losses reported in vegetables due to insect vector-borne viral and seed-borne diseases. Therefore, there is an urgent need of integrated pest/disease management (IPM/IDM) strategies to advocate managing plant diseases in vegetable crops.

Economic Impact of Fungal Diseases on Vegetable Crops

Pests (insect, fungi, bacteria, phytoplasma, viruses, viroids, weeds etc.) are devastating vegetable crops whose incidence were reported recently (Tripathi *et al.* 2021, Pandey *et al.* 2016) presented in Table 1.

Fungal Diseases of Vegetables

In recent past, with changes in farming practices, abrupt weather climate, and the introduction of new varieties/hybrids are considered major factors for the emergence and outbreak of new pathogens/diseases on vegetable crops. Important pathosystem of vegetable crops described as below:

Nursery pathosystem

In the nursery pre-and post-emergence damping off disease of vegetable crops is the major problem. Nursery of vegetable crops severely infected by damping – *off*, Rhizoctonia root rot, *Phytophthora* and gummy stem blight. In the nursery seedlings get infected near the soil surface before or after emergence. Seedling tissues become soft, water-soaked and weak causing the seedlings to topple fall down and die (Fig. 1). Damping *off* is a wide host range soil-borne diseases infecting crops like brinjal, chili, tomato, cabbage and cauliflower (Tripathi *et al.*, 2019, 2020, 2021; Tripathi 2020, 2021).

White mold - Sclerotinia rot

White mold (*Sclerotinia sclerotiorum*) appears in warm and moist weather (> 95% relative humidity) and favors fungal growth on infected pods which develops as a white, fluffy mycelial mat often with large, irregular, black-colored sclerotia, typical of *S. sclerotiorum* (Tripathi *et al.* 2014, 2014, 2016, 2017). Initially, superficial mycelium, white but later hard dark black colored sclerotia are formed on it. In almost all vegetables, *Sclerotinia* /white mold (*S. sclerotiorum*) symptom initially appear in the form of water-soaked lesions on pods and stems. Later, infected pods and fruits become whitish and covered with white mycelia mats and black-colored sclerotia. The isolated fungus was identified as *S. sclerotiorum* based on morphological and cultural characteristics of the mycelia and sclerotia (Bolton *et al.* 2006). Tripathi *et al.* (2016) highlighted the wide non-host-specific emergence of this pathogen in vegetable-growing areas under a changing climatic scenario.

Late blight - Phytophthora blight

Potato (*S. tuberosum*), and tomato (*S. lycopersicum*) are most important solanaceous vegetable crops. Late blight of tomatoes is an emerging threat for potato and tomato cultivation caused by an oomyceteous pathogen, *Phytophthora infestans*. Its incidence has been recorded upto 60% under field conditions; 90% under net house conditions on hybrid tomatoes. It has widely distributed and causes

Table 1: Emerging/re-emerging diseases on vegetable crops

Crop	*Disease*	*Disease incidence (%)/ Yield loss (%)*
Brinjal	*Phomopsis* blight	60
	White rot	10
	Collar rot	20
	Leaf blight	25
	Fungal wilt	10
Tomato	*Alternaria* blight	40
	Phytophthora blight	60
	Septoria leaf spot	10
	Late blight	60
	White rot	5
	Collar rot	20
	Fruit rot	15
Chili/ Capsicum	Die-back	35
	Anthracnose	23
	Phytophthora blight	8
	Leaf blight & fruit rot	15
	Blossom blight	30
Cucurbits	Downy mildew	30
	Sclerotinia rot	10
	Blossom blight	30
	Anthracnose	55
	Cercospora leaf spot	30
	Gummy stem blight/black rot	50
	Wine & Fruit rot	15
	Powdery mildew	8
	Phytophthora blight	35
Legumes	Leaf blight	60
	Ascochyta blight	10
	Root rot/Ashy stem rot	5
	Phoma leaf blight	12
	Rust	10
	Powdery mildew	50
	Downy mildew	15
	White rot	25
	Anthracnose	20
	Leaf spot	5
Cole crops	Leaf spot	26
	Downy mildew	10
	White rot	5
	Root rot/wire stem	8
	Black leg	2

Root crops	Leaf spot	3
	Collar rot	4
	White rot	2
	Cercospora leaf spot	2
	Soft rot	5
Okra	Leaf blight	70
	Charcoal rot	8
	Leaf spot	3
Onion/Garlic	Purple blotch	40
Leafy vegetable	Soft rot	2
Nursery of vegetable crops	Damping off	30
	Rhizoctonia root rot	20
	Phytophthora blight	40

epidemics in areas with frequent cool, moist climate. In the last couple of years, late blight has become one of the most devastating threats to the cultivation of tomatoes in eastern Uttar Pradesh (Tripathi *et al*. 2016, 2017, Rai *et al*. 2018). Initial disease symptoms appeared in the form of irregular; water-soaked and light brown lesion on leaves which are normally covered with white cottony mycelial growth on the lower side of leaves. Water-soaked brown lesions expended rapidly on stem and green fruits. Infected green fruits of tomatoes usually develop olivaceous, brown-colored leathery and hard structures. All infected fruits eventually fall of from the plants and they were neither fit for marketing nor human consumption. Microscopic studies of the colonized pathogen on potato slices revealed hyaline, coenocytic, branched hyphae and aseptate sporangiophores with lemon-shaped, papillate sporangia. Sporangia dimensions were $32 \pm 6.3 \times 20 \pm 4.9$ µm, with a length-to-width ratio of 1.6. On the basis of morphological characteristics and sporangia size, the pathogen was confirmed as *P. infestans*.

Anthracnose - Colletotrichum rot

Chili, bell pepper, gourds and beans are economically important vegetable crops, widely grown in tropical and subtropical region of the globe. Anthracnose causes heavy crop losses worldwide in vegetables (Sharma *et al*. 2005) and anthracnose ranked 8th position among top 10 most economically important plant pathogens in the world (Dean *et al*. 2012). Genera *Colletorichum* has wide host range infecting vegetables, fruits, ornamental plants and staple crops (Saxena *et al*. 2016, Mongokolporn and Tylor, 2018). The species of this genus are reported to cause anthracnose diseases in more than 121 plants genera from 45 different plant families (Farr *et al*. 2016). Infected fruits showing typical anthracnose symptoms of sunken necrotic lesions with black dot like acervuli in concentric rings collected and collected fruit samples were examined under light transmission microscope. Anthracnose (*Colletotrichum lindemuthianum*, *C. orbiculare, C. capsici*) symptoms appear on immature pods as sunken cankers with lighter or grey central areas of about 5 to 7 mm size. The spots on fruits of chili and bottle gourd and beans pods are enlarged and produce tiny black acervuli in the centers which in humid conditions ooze viscous droplets consisting of a mass of pinkish spores (Figure 2). Pure cultures of the pathogen isolates were established on PDA by hyphal tip method. Under light microscope, one-celled, smooth-walled hyline falcate, tapered-ended conidia (16–26 × 3–4 µm) and acervuli with numerous setae (15-27 x 2-5 µm), were recorded (Tripathi *et al*. 2017). In chili, anthracnose (*Colletotrichum capsici*) disease symptoms appear in the form of brown to black sunken spots and lesions on leaves, stems and pods. The centre of anthracnose lesions on pods is covered with numerous black dot-like acervuli. Browning and rotting occurred on infected ripened fruits.

Gummy stem blight - Didymella rot

Gummy stem blight (GSB) is caused by *Stagonosporopsis cucurbitacearum* (syn. *Phoma cucurbitacearum*; Teliomorph: *Didymella bryoniae*). *S. cucurbitacearum* is a seed-borne soil-borne and air-borne plant pathogen. In recent years, gummy stem blight has become a major problem for the cultivation of cucurbits. Almost all the cucurbits such as cucumber, bottle gourd, bitter gourd, pumpkin, ash gourd, ridge gourd, muskmelon, watermelon etc. are infected by gummy stem blight. Initially, water-soaked area are observed on the stem near soil line. Later on translucent gum-like exudates released from the affected portion is deposited over it. Usually, silvery grey to dark brown lesions often observed near the stem base which causes girdling of stem and finally kills the plant. Cankers may form on crowns, main stems or vines of plants with numerous black pycnidia on it. Drops of gummy, amber-colored plant

Damping off on tomato | *Damping off* on chili | *Damping off* on chili | Gummy stem blight on sponge gourd

Fig. 1: Nursery diseases of vegetable crops

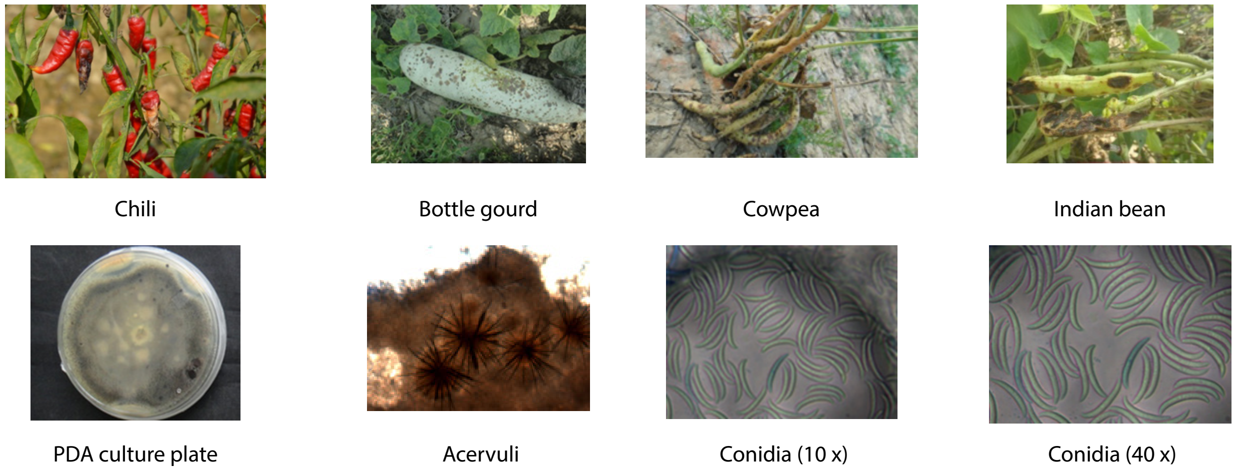


Fig. 2: Typical symptoms *Colletotrichum fruit* rot (anthracnose), culture, acervulli and conidia

sap appear on some cankers under certain conditions. Black dot-like pycnidia is also observed on the infected stems/bark, leaves and fruits. Its incidence was recorded on cucumber, bottle gourd, ash gourd and watermelon in field and polyhouse (Fig 3). Inoculated PDA plates were produced white mycelium after 4 weeks of incubation at 24ºC. Conidia were cylindrical non-septate to monoseptate and 60 x 40 µm in size. Based on the morphological and microscopic characteristics, the pathogen was identified as *Stagonosporopsis cucurbitacearum* (syn. *Didymella bryoniae*) (Tripathi *et al*. 2019, 2021). It infects all above-ground vegetative and reproductive parts of cucurbits including leaves, petioles, veins, stems, tendrils, pedicels, flowers, peduncles, fruit and seed. Pathogen propagules survive on the plant debris from previous crops on infected plant debris.

Phomopsis – blight

Brinjal (*Solanum melongena*, Solanaceae) is one of the most important vegetables worldwide. *Phomopsis vexans* is one of the notorious seed-borne fungal pathogens that causes destructive *Phomopsis* blight which ranked second topmost disease of brinjal in India. Brinjal fruit rot due to the incidence of this disease have been estimated up to 60%. The pathogen was identified on the basis of colony morphology and size of conidia (20–40 x 40 µ) (Fig 4). In brinjal, *Phomopsis* blight (*P. vexans*) symptoms appear as circular, large, light brown lesions on leaves, partial drying of the stem, light brown rotting on fruits. Black dot like pycnidia visible on diseased portion.

Alternaria - rot

Alternaria solani and *Sclerotiorum rolfsii* cause fruit rot in tomatoes. Black spot symptoms on peduncle and fruits result in the production of circular colored lesions bearing dark margins. *Alternaria* spp. causes brown rot in tomatoes and cauliflower. In tomato, Alternaria blight (*Alternaria solani, A. alternata*) appears as concentric irregular brown spots on leaves, stem, petioles and fruits, and zonation on spots. *Alternaria* black spot (*A. brassicae, A. brassicicola*) appears as dark brown circular lesions with concentric zones with shot hole in the blotching lesions.

Mildew and rust

Downy mildew (*Pseudoperonospora cubensis*) appeared in the form of irregular light brown yellow lesion on gaurds and melons (Pandey *et al*. 2018). *Peronospora viciae* and *Peronospora pisi* cause downey mildew on leguminous vegetables which symptom appears in the form of greyish-whitish fungal growth on the upper leaf surface and yellowish/brownish patches on the underside of the leaf including pods during cool and humid conditions. Powdery mildew caused by *Sphaerotheca fuliginea* on cucurbits however, *Erysiphe polygonii* and *E. pisi* on leguminous vegetables in which disease symptom appears in the form of talcum powder like whitish growth on foliage and stem of the plants. Rusts (*Uromyces pisi /U. phaseoli*, *U. fabae* and *U. pisi)* symptom appears in the form of any small to large orange-brown colored pustules on the lower and upper surface of leaves including pods.

Charcoal rot or ashy stem blight

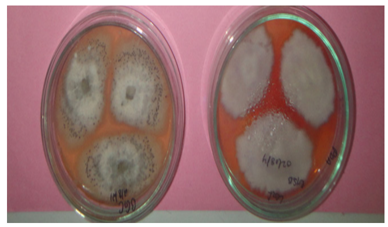
Charcoal rot or ashy stem blight *Macrophomina phaseolina* (*Rhizoctonia solani*) disease symptoms appear in the form of dark brown to black charcoal-colored lesions covered with black dot-like fruiting bodies (resting micro sclerotia and pycnidia) on pods. Charcoal rot or Ashy stem blight is caused by *M. phaseolina* (*Rhizoctonia solani*) on various vegetable crops (Meena *et al*. 2018). The disease symptom appears in the form of dark brown to black charcoal-colored lesions covered with black dot-like fruiting body (resting microsclerotia and pycnidia) on the collar region of the stem. The stem portion can be easily peeled of and pulled out from the soil.

Symptoms of gummy stem blight on ash gourd leaves

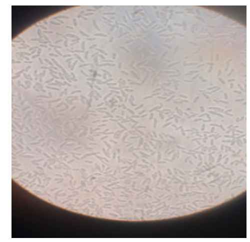
Symptoms of gummy stem blight on cucumber leaves

Symptoms of gummy stem blight on bottle gourd leaves

Symptoms of gummy stem blight on fruit and stem of bottle gourd



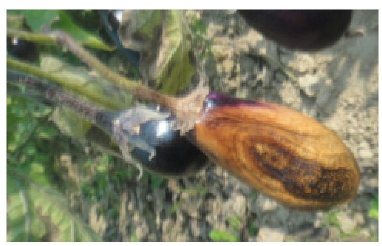
PDA culture plate



Conidia

Fig. 3: Typical symptom of gummy stem blight, culture plate and conidia

Brinjal

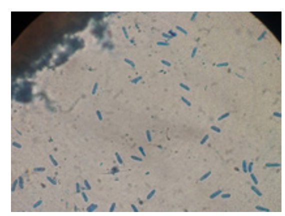


Brinjal

Brinjal

Brinjal

PDA cultutre plate



Conidia

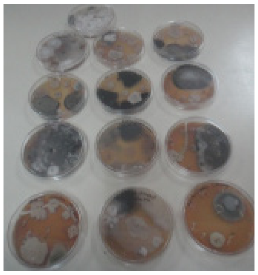
Fig. 4: Typical symptom of *Phomopsis* blight, culture plate and conidia

Ascochyta – blight

Ascochyta blight (*Ascochyta pisi*) black spot symptoms on pods result in the production of round tan-colored sunken spots bearing dark margins with pycnidia. Pycnidia develop in the centres of such spots on pods.

Emerging and Re-emerging Postharvest Fungal Diseases

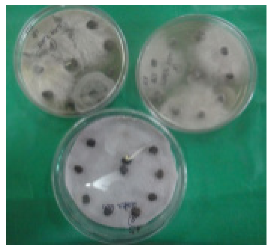
In general, postharvest diseases and losses of vegetables are incited by fungi and bacteria. Common postharvest diseases resulting from wound infections initiated preharvest and postharvest include blue and green mold (*Penicillium* spp.), nesting disease of pea caused by *Pythium* spp., *Colletotrichum* spp. and grey mold rot caused by *Botrytis cinerea* and transit rot (*Rhizopus stolonifer*). Fruit rot incidence of several post-harvest pathogens viz. *A. solani* (30%), *P. infestans* (15%), *R. solani* (30%), *S. rolfsii* (30%) fruit rot on tomato; *C. dematium* fruit rot (20%) on chili; *P. vexans* (60%) fruit rot on brinjal; *A. pisi, C. lindemuthianum*, *S. sclerotiorum*, *Alternaria* blight on leguminous vegetables; *Stagnosporopsis* (*didymella)* black rot (50%) and *Colletotrichum* anthracnose (20%) on fruits of bottle gourd, pumpkin, ash gourd and watermelon were



Brinjal seeds plated on PDA

Bottle gourd seed on blotter paper

Cluster bean seeds plated on PDA



Phomopsis on cluster bean

Colletotrichum lindemuthianum in seeds of Indian bean

Phomopsis on cowpea

Fig. 5: Blotter test for detection of seedborne pathogens

recorded (Mehrotra and Agarwal 2003, Tripathi *et al*. 2021, Tripathi, 2021, 2022).

Seed Borne Fungal Diseases

Seeds are basic input for vegetable production. Seed-transmitted pathogens such as fungi, bacteria, viruses and nematodes have been detected in 400 genera of more than 100 plant families. Richardson (1990) published a list of more than 1500 fungi belonging to 287 genera reported to be seed-borne on 534 crops of economic importance. Seed transmission is the most important mode of long-distance dissemination of pathogens and carries over from season to season (Neergard, 1979). Evaluation of seed health is very important for profiling of seed-borne pathogens and decision-making towards disease-free seed production, seed storage, seed certification, safer seed treatment, management of seed-borne diseases (pathogens), safe trans- boundary movement of seeds and quarantine regulation for long-term seed health management (Tripathi *et al*. 2021).

Seed health status of 210 seed samples of conserved/stored seeds of vegetable crops were subjected for evaluation of seed health. Fungal pathogens were identified on the basis of habitat characteristics on blotter paper and colony morphology on potato dextrose agar (Fig 5). Important seed-borne fungal pathogens namely *Phomopsis vexans, Curvularia lunata, Alternaria, F. oxysporum, Macrophomina phaseolina* on brinjal**;** *Colletotrichum dematium, Alternaria spp., Fusarium solani* on chili; *Alternaria* spp.**,** *F. oxysporum* on tomato; *A. brassicae, A. brassicola* on cabbage and cauliflower; *Fusarium* spp., *Didymella brayoniae* on bottle gourd; *Macrophomina phaseolina, Phoma* sp., *Colletotrichum, Phomopsis, Fusarium* on cluster bean; *Sclerotinia sclerotiorum , Fusarium, M. phaseolina, Colletotrichum* on Indian bean, *Sclerotinia sclerotiorum* on French bean; *Fusarium, Alternaria* spp., *Macrophomina phaseolina* on cow pea and *A. pinodes*, *A. pisi*, *B. cinerea*, *F. moniliforme, S. sclerotiorum* on pea were recorded (Tripathi *et al*, 2015; Tripathi and Singh 2022). Moreover, so for no much research works has been done in vegetable seed pathology to evaluate the health status of vegetable crop seeds/germplasm conserved under seed/gene bank facility.

Detection of Fungal Plant Pathogens

Pathogens were isolated on agar medium and identified on the basis of macroscopic and microscopic analysis of colony and conidia/spore morphology by microscopy, Sero-diagnostics (ELISA, Dot-blot assays) and nucleic acid (PCR) based methods. The identification of the seed-borne fungal pathogen is based on the way they grow on seeds 'habit characters' in the blotter method assisted by optical microscopy (Neergard 1973, Mathur and kongsdal 2003, Singh *et al*. 2016).

Disease Management

Concept of integrated disease management is employed as a strategic approach for pest and disease management in vegetable crops. The principles of integrated disease/pest management are based on avoidance, exclusion, eradication, protection and host resistance. Integrated disease management includes cultural, host resistance, biological and chemical management. Disease management involves in reduction of amount of pathogens inoculum and rate of spread of pathogen inoculum. Integrated disease management (IDM) strategies advocate managing vegetable diseases with judicious use of synthetic pesticides (Pandey *et al*. 2016, Lognathan *et al*. 2016). For the management of these pests, various established, innovative and eco-friendly tools and techniques can be applied to keep the pest under control. It is, therefore, urgent need of location-specific survey and surveillance for scouting and monitoring of pathogens and mapping of diseases of vegetable crops for their cost-effective management. Techniques of plant disease management of vegetable crops have been described here.

Table: 2. Biological control of fungal diseases of vegetable crops

Plant pathosystem	*Bioagents*
Bottlegourd Wilt (*F. oxysporum),* Bottlegourd Root rot (*R. solani),* Bottlegourd Collar rot (*Sclerotinia sclerotiorum)*	*T. viride*, *T. virens, B. subtilis*
Cauliflower root rot (*Rhizoctonia solani),* Cauliflower Stalk rot (*S. sclerotiorum),* Chinese cabbage (*Plasmodiophora brassicae)*	T. harzianum, B subtilis
Cucumber Seedling diseases (*Phytophthora* or *Pythium Fusarium oxysporum* f. sp. *cucumerinum),* Cucumber Seedling diseases (*Phytophthora* or *Pythium)*	*T. harzianum*
Brinjal Collar rot (*S. sclerotiorum),* Brinjal wilt and Damping *off* (*F. solani, P. aphanidermatum)*	*T. viride, T. virens*
Tomato Damping off and wilt (*F. oxysporum,* f. sp. *Lycopersici),*Tomato *(Ralstonia solanacearum)* Tomato root knot *(Meloidogyne incognita)*	*T. harzianum*, *P. fluorescens,* Phage Phi RSL1
Chili Fruit root and die back (*Colletotrichum capsici),* Chili Root rot (*S. rolfsii)*	*T. viride, T. harzianum, B. subtilis, Actinomycete*
Fenugreek Root rot (*R. solani),* French bean Root rot (*R. solani)*	*T. viride, T. hamatum*
Pea Seed and Collar rot (*Pythium),* Pea White rot (*S. sclerotiorum)*	*T. viride*
Cowpea Wilt (*F. oxysporum* f. sp. *ciceris)*	*T. viride*
Pepper (*Phytophthora capsici)*	*B. subtilis* R33 *B. subtilis*

Soil Solarisation

Soil solarisation by the use of white transparent polythene in hot summer is one of the most effective approaches for the management of soil-borne diseases particularly in nursery beds, high-value horticultural crops and green house crops. The main objective is to eliminate soil-borne pathogens like *Macrophomina phaseolina, Fusarium oxysporum f sp. Pisi, meloidogene spp. Pseudomomnas* sp., *Streptomyces scabies, Verticillium dahlia, Phytophthora* spp., *Pythium* spp., *Phomopsis, Rhizoctonia, Sclerotium*, *S. rolfsii* etc.

Organic Matter

Organic matter has a major impact on disease suppression and inoculum reduction of soil borne plant pathogens viz. *Pythium* damping off and *Phytophthora* blight, *Aphaenomyces* root rot of pea, *Rhizoctoni*a root rot of bean and radish, *Fusarium* wilt of cucumber and *Phytophthora* crown rot of pepper. *Trichoderma* spp., *Streptomyces* spp., *Pseudomonas* spp., *Bacillus* spp., *Enterobacter* spp., *Flaviobacterium balustinum* have been identified as biological agents in compost (Singh *et al*. 2021, Tripathi 2021, Srivastav and Tripathi 2021).

Crop Rotation

Crop rotation with cereals is quite effective in reducing the incidence of root-knot nematode and wilt of pea. Fallowing is effective against *S. Rolfsii* and *Verticillium dahlia* because sclerotia quickly degenerate under the influence of alternate drying and wetting of the soil. Mixed cropping and large-scale cropping of multiple isogenic lines are better than monoculture of genotypes to avoid outbreak of a plant disease in vegetable crops.

Grafting

Bottle gourd has a vigorous root system as well as higher degree of gummy stem blight disease resistance and tolerance so that it is preferred by farmers, growers, and researchers as root stock for grafting to prevent crop losses caused by soil-borne fungal diseases. Eleven cultigens of cucurbits viz. bottle gourd (Kashi Ganga, Legacy, VBRTG-61, Maxima), bitter gourd (IC-2125004), ash gourd (Kashi Dhawal), cucumber (summer fit, Hardwickii), sponge gourd (Kashi Shreya, VRRG-68-2011, VRRG-75-2016), ridge gourd (Kashi Sivani) was screened against gummy stem blight under pot and leaf detached method. Based on the disease reaction on tested cultigen under green garden shed net and PDI calculated, cultigens viz. summer fit (An interspecific hybrid of squash), *Cucumis* hardwicki and bitter gourd IC-2125004 were found most resistance root stock for grafting (Tripathi *et al*. 2021).

Biological Control

Biological control is used through microbes such as fungi, bacteria, actinomycetes and viruses (bacteriophages) to control postharvest disease of vegetables (Pandey *et al*. 2016, Loganathan *et al*. 2016, Chaurasia *et al*. 2018; 2019, Tripathi *et al*. 2019, 2020). Indiscriminate use of synthetic pesticides for preventing and controlling crop diseases adversely affects the environment, microbiome, development of resistance and hormoligosis in several plant pathogens and also acts as serious non-tariff barrier to trade of vegetable commodities. Presently biopesticides like *Trichoderma* and *Pseudomonas* are being used in many vegetable crops (Tripathi *et al*. 2020, Tripathi 2018). As per estimates Indian bio-agents market is equivalent to 2.5% of total pesticides market and global market of biocontrol agents was almost $ 4.0 billion in 2020 with a projection towards 0.6 billion by 2027 (Anonmm 2020). Due to adverse impact of pesticides on soil and microbiota farmers look forward to bio-pesticides and biocontrol agents for biological control of pests and plant diseases (Collinge *et al*. 2022, Tripathi 2017, Ciancio *et al*. 2016, Lorito *et al* 2010, Ehlers 2011). Soil-borne diseases namely damping-off in nursery, root rot, wilt, collar rot, fruit rots, charcoal rot and gummy stem blight major threat are caused by several species of genera of *Pythium, Phytophthora, Rhizoctonia, Scerotium, Fusarium, Sclerotinia, Verticillium, Macrophomina Phoma, Colletotrichum, Didymella* and *Meloidogyne*. The important target pathogens for biological control are *Pythium* spp. *Sclerotium rofsii*, *Fusarium* spp. *Rhizoctonia solani*, *Phytopthora* spp, *Phoma, Sclerotina sclerotorum, Verticillium, Erysiphe* (Table 2). *Trichoderma* is effective against several pathogens like *Pythium, Fusarium, Sclerotium, Macrophomina* and *Rhizoctonia*. Ampelomyces quisqualis is effective against powdery fungi like *Erysiphe* and *Uncinulla*. *Sporidesmium sclerotivorum* is effective against *Sclerotinia* spp. of vegetables. Combination of *T. viride* + *P. fluorescens* is very effective to control *Phytophthora* blight in chili. Among the bacteria, *Pseudomonas fluorescence* has shown effectively in cheking growth of *R. solani*, *Sclerotinia sclerotiorum* and *Phytophthora megasperma. Aspergillus niger* have been found antagonistic against *Fusarium oxysporum* causing wilt of muskmelon and watermelon. Agriculturally important microorganism plays an important role in control of plant pathogens and stimulation and promotion of plant growth (Manjunath *et al.* 2010, Tripathi *et al.* 2020, 2019). Generally, bio-control agents are used @5–10 g/kg for seed treatment and 10–25 g per square meter for nursery bed application. Integration of neem cake @50 g and bio-agents *T. viride* @10 g/m^2 area recorded 76.3% tomato seedling stand. Application of talc-based formulations of *Bacillus subtilis* (BS2-IIVR strain) having minimum cfu of 2.5X10^8 as seed treatment @4g/kg seed, soil application as 10g/m^2 and soil drenching @5%, has recorded reduced damping off incidence on tomato (15.22%) and brinjal (33.18%) with maximum cost benefit ratio (CBR) 1: 7.99 and 1: 3.66, respectively with improved germination percentage over control (Tripathi *et al.* 2019, Herman 1991).

IIVR strain- *Trichoderma asperellum* was evaluated in tomato and French bean for disease management. Among treatments *T. asperellum* (IIVR-strain, 2×10^7 cfu/g), was found most effective for germination (72%) with compare to control (50%). Maximum vigor index (1274) and lowest damping off (2%) recorded with the treatment of *B. subtillis* (IIVR-CRB7, 2.5×10^{11} cfu/g), in tomato with comparison to control (13%), respectively. Talc based formulation of bioagents, *B. subtillis* (IIVR-CRB7, 2.5×10^{11} cfu/g), *Trichoderma asperellum* (IIVR-strain, 2×10^7 cfu/g), IIVR-TGV(1.5X 10^7), IIVR-TCV (1.6 x 10^8), *Actinomyces* N 1.2 (5.30 x 10^6 cfu/g) and Kashi Jaivshakti (10×10^{12} cfu/g) were applied as seed treatment @4 g/kg and soil application with bioagents fortified vermicompost (1:150) @600g/m^2 in nursery bed (6 X 1 m^2) of tomato (Kashi Aman) *(*Tripathi 2022). However, lowest *Sclerotinia sclerotiorum* stem rot (3%) was recorded in French bean (Kashi Rajhansh) with *B. subtillis* applied as seed treatment @10 g/kg and soil application with bioagents fortified vermicompost (1:150) & foliar spray @1% at 45 days after sowing in compare to control (26%). Highest germination (69.5%), vigor index (1153.7) and lowest *Rhizoctonia* root rot (2%) were recorded with seed treatment of *T. asperellum (*IIVR strain; 2×10^7 cfu/g in Indian bean (VRSEM 3) in comparison to in control (Tripathi *et al.*, 2021).

Soil application and seed treatment are only feasible methods of using bioagents under the field conditions. Seed treatment is preferred in direct sown crops, whereas soil application and seed treatment are feasible in nursery crops. Best utilization of any biocontrol agents in soil is only possible when it is supplemented with well-decomposed organic amendments, congenial moisture and protected from extreme weather conditions till it is established in soil. There are several methods of delivery of bio control agents' viz. seed treatment with *P. fluorescens* 0.5% WP @10 g/kg , *T. viride* 1.0% WP @4 g/kg seed; soil application with *T. viride* 1% WP @2.5 kg mix with the 150 kg of compost, seedling root dip treatment *T. viride* 1.0% WP @10 g/l of water for 15 to 30 min were standardized in brinjal, chili, tomato, cauliflower and cabbage.

Management of postharvest spoilage is becoming a very difficult task because the pesticides/chemicals available are rapidly declining with consumer concern for food safety. Application of good postharvest management practices which are supported by good technologies and also improving postharvest systems will maintain the quality of vegetables and reduce quantitative losses. A holistic approach is needed for regulating aflatoxins under the trade/export market with biosecurity including bio-warfare, biodiversity and biosafety for liberalized trade under the World Trade Organization (WTO) (Tripathi *et al.* 2013).

International markets reject produce containing unauthorized pesticides, with pesticide residues exceeding permissible limits, and with inadequate labeling and packaging. Hence, biological control of postharvest diseases has great potential because postharvest environmental conditions like temperature and humidity which can be strictly controlled to suit the needs of the biocontrol agent. Biocontrol of postharvest diseases of vegetable crops has great potential under storage conditions. The bio pesticides Ecogen US (Aspire™), Azotobactor (Bio-Save™) and Anchor (Yield Plus™) are involved to combine products with a low level of fungicide and salt solutions (calcium chloride or sodium bicarbonate @1–2%) and other food additives to improve efficacy against postharvest diseases. EcoSMART formulation based on rosemary oil, viz. EcoTrol™, Sporan™ (fungicide) and eugenol oil formulation Mataran™ (weedicides) are recognized as safe plant protectants. Therefore, the postharvest application of eco-friendly control methods may be exploited to manage the disease of vegetables. An effort has been made to develop two new products based on yeast antagonist *C. saitoana* and a derivative of either chitosan (Biocoat) or lysozyme (Biocure). Additives such as sodium bicarbonate are found highly effective to increase biocontrol efficacy to levels equivalent to those found with available postharvest fungicides. The product is marketed under the name ProYeast-ST and ProYeast-ORG in Israel by the company AgroGreen and found effective against rots incited by *Botrytis*, *Penicillium*, *Rhizopus* and *Aspergillus*.

Botanical Pesticides

Botanical pesticides cause no adverse effects on non-target biota with biodegradability. It should be noted that most of the crops sprayed with botanical pesticides are quite safe for consumption after a short period after spraying. The use of natural botanical products would be a supplement or an alternative to synthetic fungicide. Examples include 1,8-Cineole, the major constituent of oils from rosemary (*Rosmarinus officinale*) and eucalyptus (*Eucalyptus globus*), eugenol from clove oil (*Syzygium aromaticum*), thymol from garden thyme (*Thymus vulgaris*) and menthol from various species of mint (*Mentha* species). The majority of research is progressing in this regard to develop plant oil–based pesticides.

Many exhaustive studies have been carried out on the utility of neem oil against various fungal pathogens. Its efficacy has been evaluated against fungal pathogens and found to be on par with the fungicide hymexazole in the control of the soil pathogens *F. oxysporum*, *F. ciceri*, *R. solani*, *S. rolfsii* and *S. sclerotiorum*.. SPIC Science Foundation has developed a fungistatic product "Wanis" which has a single monoterpene as an ingredient and it is reportedly very effective in controlling more than 30 different types of phytopathogenic fungi. It is nontoxic to human beings and livestock. Recently, an antifungal agent by the name "TALENT", containing carvone as the active ingredient, derived from essential oil of Carumcarvii, was commercialized. Mycotech Corporation

Table 3: Label claimed fungicide for vegetable diseases control

Crop	*Pesticide (a.i.)*	*Dose (of formulation) (%)*	*Target disease/pest*	*Waiting days (PHI)*
Tomato	Azoxystrobin	0.1%	Early blight, late blight	3
	Mancozeb	0.25%	Early blight & late blight	5-6
	Propineb	0.3%	Buck eye rot	10
	Cymoxanil 8% + Mancozeb 64%	0.25%	Late blight	10
	Famoxadone 16.6% + Cynoxanil 22.1%	0.1%	Early & late blight	3
Chili	Azoxystrobin	0.1%	Fruit rot	5
	Copper Sulphate	0.2%	Fruit rot, powdery mildew, leaf spot	3
	Captan	0.3%	Fruit rot, Anthracnose	5
	Chlorothalonil	0.1%	Fruit rot	10
	Flusilazole	0.02%	Powdery mildew	5
	Kitazin	0.2%	Fruit rot, dieback	3
	Propineb	0.5%	Die back	10
	Sulphur	0.4%	Die back	
	Tebuconazole	0.1%	Fruit rot, powdery mildew	5
	Captan+ Hexaconazole	0.1%	Fruit rot, Anthracnose	5
Brinjal	Manozeb	0.2%	*Alternaria* leaf spot/Early blight	5-6
	Capton	0.2%	*Alternaria* leaf spot/Early blight	5
	Zineb	0.2%	Phomopsis fruit rot or blight	-
Cucurbits	Thiophanate methyl	0.2%	Powdery mildew, Anthracnose	1
	Cymoxanil 8%+ Mancozeb 64%	0.3%	Downy mildew	10
	Chlorantranilprole			7
	Cyantraniliprole			5
Legumes	Fenarimol	0.04%	Powdery mildew	15
	Wettable sulphure	0.3%	Rust	-
	Triadimefon	0.05%	Rust	-
	Azoxystrobin	0.1%	White stem rot	-
Cole crops	Manozeb	0.2%	*Alternaria* leaf spot	-

product Cinnamite™, based on cinnamon oil, has been developed as a fungicide/miticide for glasshouse and horticultural crops. World-leading essential oil-based pesticide-producing EcoSMART technologies developed EcoPCORR under the name Bioganic™ as insecticide and miticide for nursery crops, horticultural crops and value-added crops under glasshouse conditions. The EcoSMART formulation based on rosemary oil,viz. EcoTrol™ (insecticide/miticide), Sporan™ (fungicide) and eugenol oil formulation Mataran™ (weedicides) were classified as generally recognized as safe (GRAS). Commercially available bio-agents and botanicals were applied as seed treating agents in bottle gourd (Kashi Ganga) @ 2000 ppm/kg seed in which *T. viride* was found effective for seed germination (48.88%) and vigour index (537.77) in comparison to control (35.55%, 248.88). However, botanical specially phytotonic supersonata (HPM Chemicals & Fertilizers Ltd.) was found phytotoxic and causes seed necrosis. These chemicals of biological origin are safe to use, and in a few cases can even be produced by farmers and rural communities. Thus plant essential oils are safe to the user and the environment and have a good potential as crop protectants and integrated pest management under organic farming and value-added agricultural and horticultural crops (Tripathi *et al*. 2014). Commercially available bio-agents and botanicals were applied as seed treating agents in seeds of different crops.

Fungicides

Fungicides are the most powerful and commonly used for the control of fungal diseases. However, excessive reliance on chemicals has posed several adverse impacts such as a buildup of pest resistance to pesticides (fungicides, insecticides, bactericides and weedicides), harmoligosis, an outbreak of secondary pests, harmful to non-target organisms, health hazards, underground water and environmental pollution (Tripathi *et al.* 2021, Tripathi *et al*. 2020, Tripathi 2019, Tripathi 2016). Chemical fungicides are commonly used for the management of postharvest disease in vegetables (Rai *et al*., 2014). For postharvest pathogens that infect produce before harvest the fungicides should be applied at field level during the crop season, and/or strategically applied as systemic fungicides. At the postharvest level, the fungicides are often applied to reduce infections already established in the surface tissues of produce or they may protect infections occurring during storage and handling. Fungicides used during postharvest are actually fungistatic rather than fungicidal under normal usage. The fungicides are applied on the produce as dips, sprays, fumigants, treated wraps and box liners or in waxes and coatings. Dip and spray methods are very common in postharvest treatments. The fungicides generally applied as dip or spray method are benzimidazoles (e.g. benomyl and thiabendazole) against anthracnose, and triazoles (e.g. prochloraz and imazalil) and fumigants, such as sulfur dioxide, for the control of grey mold used for postharvest disease control. Dipping in hot water (at 50°C for 5–10 minutes, depending on the size of the produce in combination with the fungicide) is also used for effective control of disease. Sodium hypochlorite as a disinfectant is used to kill spores of pathogens present on the surface of the vegetable produce. Crop-wise chemical management options for major vegetable disease are listed in Table 3 as ready reference.

Future Prospective

Finally, it may be concluded that fungal disease management is a systems approach that looks at the whole ecosystem including understanding how the fungal pathogens interact with their host plants and general climatic conditions. Further, Integrated disease management is an economical, sustainable and viable approach to manage fungal plant diseases and insect vectors. Emphasis on bio-control and regulation for judicious use of chemicals has been increasing for managing of diseases of vegetable crops. It is, therefore, urgent need of planning for location-specific survey and surveillance for scouting and monitoring and mapping of pathogens/diseases of vegetable crops for their cost-effective management.

References

Anon (2020) Biopesticides market size, share & COVID-19 impact analysis, by type (Bioinsecticide, Biofungicide, Bionematicide, and Others), source (Microbials and Biochemicals), mode of application (Foliar application, seed treatment, soil treatment, and others), crop (cereals, oilseeds, fruits & vegetables, and others), and regional forecast, 2020–2027. Available at: https://www.fortunebus inessinsights.com/industry-reports/biopesticides-market-100073

Chaurasia A, Meena BR, Tripathi AN and Pandey KK (2019) Actinomycetes: a promosing unexplored microorganisms for vegetable crops. In book of abstracts I Vegetable Science Congress on Emerging Challanges in Vegetable Research and Education (VEGCON-2019) 01-03 February, 2019, Agriculture University Jodhpur, Rajasthan, p 205.

Chaurasia A, Meena BR, Tripathi AN, Pandey KK, Rai AB and Singh B (2018) Actinomycetes: an unexplored microorganisms for plant growth promotion and biocontrol in vegetable crops. World J of Microbiol and Biotechnol 34:132. https://doi.org/10.1007/s11274-018-2517-5.

Ciancio A, Pieterse CMJ and Mercado- Blanco J (2016) Editorial: Harnessing useful rhizosphere microorganism for pathogen and pest biocontrol. Front. Microbiol. 7: 1620

Collinge DB, Jensen DF, Rabiey M, Sarrocco S, Shaw MW, Shaw RH (2022) Biological control of plant diseases – What has been achieved and what is the direction? Plant Pathology, 71: 1024–1047

Dean R, Van Kan JAL, Pretorius ZA *et al*., 2012. The top 10 fungal pathogens in molecular plant pathology. Molecular Plant Pathology 13, 414–30

Ehlers, RU (2011) Regulation of biological control agents and the EU policy support action REBECA. In: Ehlers, R.U. (Ed.). Regulation of biological control agents. Dordrecht: Springer Netherlands. pp. 3–23

Harman GE (1991) Seed treatments for biological control of plant disease. Crop Protection. 10, 166-171.

Loganathan M, Rai AB, Pandey KK, Nagendran K, Tripathi AN and Singh B (2016) PGPR *Bacillus subtilis* for multifaceted benefits in vegetables. *Indian Horticulture*, *61*(1), 36-37.

Lorito M, Woo SL, Harman GE and Monte E (2010) Translational research on *Trichoderma:* from 'omics to the field. Annual Review of Phytopathology, 48, 395–417.

Manjunath M, Singh A, Tripathi AN, Prasanna R, Rai AB and Singh B (2017 Bioprospecting the fungicides compatible *Trichoderma asperellum* isolate effective against multiple plant pathogens in vitro. *J. Environ. Biol*. 38, 553-560.

Manjunath, M., Singh, Arpita, Tripathi, A.N., Rai, A.B. and Singh, B. 2016. Bioprospecting of *Trichoderma asperellum,* a biocontrol agent from *Pisum sativum L. In: Book of souvenir & abstract,* National Symposium on Vegetable legumes for soil and human health 2016, ICAR-IIVR, Varanasi, Uttar Pradesh, India, 358.

Mathur SB and Kongsdal O (2003). First ed. Common Laboratory Seed Health Testing Methods for detecting Fungi. *ISTA, Switzerland*.

Maxmen A. 2013. Crop pests: Under attack. Nature, 501, 15–17.

Meena BR, Nagendran K, Tripathi AN, S Kumari, Sagar V, Gupta N, Rai AB and Singh B (2018) First Report of Characoal Rot Caused by *Macrophomina phaseolina* in *Basella alba* L. in India. Plant Disease, https://doi.org/10.1094/PDIS-01-18-0152

Mehrotra RS, Aggarwal A (Eds.) (2003). Plant Pathology. Tata McGraw-Hill, New Delhi.

Mongkolporn O and Taylor PWJ (2018) Chili anthracnose: Colletotrichum taxonomy and pathogenicity. Plant Pathology, 67(6), 1255-1263.

Neergard P (1973) Detection of seed borne pathogens by culture tests. *Seed Science and Technology*. 1: 217-254.

Neergard P (1979) Seed Pathology. Vol I and II. The Macmillan Press Ltd. London and Basingstoke, U. K. Pp 1191.

Pandey KK, Nagendran K, Tripathi AN, Manjunath M, Rai AB and Singh B (2016) Integrated disease management in vegetable crops. Indian Horticulture. 61 (1), 66-68. https://epubs.icar.org.in/index.php/IndHort/article/view/88442

Pandey S, Rai AB, Roy Shubhdeep, Singh AK. and Tripathi AN (2018). Khira Ki Vaigyanik Kheti. ICAR-IIVR, Extension Folder No. 4/2018.

Rai AB, Loganathan M, Halder J, Venkataravanappa V and Naik PS (2014). *Eco-friendly Approaches for Sustainable Management of Vegetable Pests*. ICAR-IIVR Technical Bulletin No. 53, pp. 104.

Rai N, Rai AB, Prasanna HC, Kumar R, Halder J, Tripathi AN, Reddy YS, Kurkute S and Singh AK (2018). Tamatar ki Vaigyanik Kheti. ICAR-IIVR, Extension Folder No. 12/2018.

Richardson MJ (1990) An Annotated List of Seed-Borne Diseases. Fourth ed. ISTA, Zurich, Switzerland. Pp 387.

Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N and Nelson A (2019) The global burden of pathogens and pests on major food crops. Nature Ecology & Evolution, 3, 430–439.

Saxena A, Raghuwanshi R, Gupta VK and Singh HB (2016) Chili anthracnose: the epidemiology and management. Frontiers in Microbiology, 7, 1527.

Sharma PN, Kaur M, Sharma OP, Sharma P, Pathania A (2005). Morphological, pathological and molecular variability in Colletotrichum capsici, the cause of fruit rot of chilies in the subtropical region of north-western India. Journal of Phytopathology 153, 232–7

Singh B, Halder J, Tripathi AN and Rai AB (2016) Emerging threats of insect pests and disease in vegetable ecosystem under changing climatic scenario: An appraisal. In. National symposium on Impact of climate change, biodiversity and good plant protection practices on crop productivity. Held at Farmers' Academy & Convention Centre, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, pp-43-44.

Singh R, Singh PM and Tripathi AN (2019) Beej janit rogon ki pahchan. Sabji, ICAR-IIVR, 13 (1), 23-27.

Singh SK, Rani V and Tripathi AN (2021). Krishi me sukhasm jeevanuyon ka mahatav. *Sabji Kiran* (Rajbhasha Patrika), ICAR-IIVR, 15(1), 33-36.

Srivastav K and Tripathi AN (2021). Kenchuyen ki prajatiyan, unki pahchan evm Kchua khad banane. me unki bhumik . ICAR-IIVR Training Manual No. 97, Pp.15-27.

Thind TS (2011) Plant Pathology in India: Vision 2030. *Indian Phytopath*. 294.

Tripathi AN (2017) Status and prospects of bio agents for biological control of plant diseases. *Advanced Vegetable Production Technologies for Enhancing Productivity and Nutritional Security. ICAR-IIVR Training Manual No. 73,* 291-302.

Tripathi AN (2019) Sabjiyon me pidaknashiyon ka surakhit prayoga. Sabji Kiran, ICAR-IIVR, 13 (1), 28-33.

Tripathi AN (2019) Status and Prospects of Bio agents for Biological Control of Plant Diseases. (Eds.) Krishna H, Tripathi AN, Singh N, Roy S and Singh J. A*dvanced Vegetable Production Technologies for Enhancing Productivity and Nutritional Security.* ICAR-IIVR Training Manual No. 86. 239-258.

Tripathi AN (2021) Detection and diagnosis of emerging postharvest pathogens (diseases) in vegetable crops. In: Book of Souvenir and abstracts of International e-Conference on Postharvest Disease Management and Value Addition of Horticultural crops, ICAR- IARI, New Delhi, p 7.

Tripathi AN (2021) Emerging diseases and their management in vegetable crops. Webinar on Applied Microbiology and Beneficial Microbes, p 8.

Tripathi AN (2021) Prevalance, characterization and management of emerging pathogens (diseases) in vegetable crops. In: Vegetable Research and Innovations for Nutrition, Entrepreneurship and Environment. International Conference at ICAR-Indian Institute of Vegetable Research, Varanasi, p327.

Tripathi AN (2021) Profiling of emerging/re-emerging post-harvest diseases in vegetable crops. Journal of Agronomy & Agricultural Science, 2689-8292, 12.

Tripathi AN (2022) Detection and Diagnosis of Emerging Postharvest Pathogens Diseases in Vegetable Crops. In Management of Postharvest Diseases and Value Addition of Horticultural, Today and Tomorrow's Printers and Publishers, New Delhi. 11-18.

Tripathi AN and Singh SK (2021) Sabjiyon me prayog hetu pidak nashiyon ke panjikaran ki disha evm dasha. *Sabji Kiran*, ICAR-IIVR, 15(2), 77-79.

Tripathi AN, Agarwal PC, Khetarpal RK, Bhat KV, Vishunavat Karuna and Singh US (2011) Genetic variation in *Fusariummoniliforme* isolates from seeds of different crop species. Indian Phytopath. 64(2): 173-177.

Tripathi AN, Anant Bahadur and Behera TK (2021) Gummy stem blight: An emerging disease of cucurbitaceous vegetables. ICAR-IIVR, Vegetable- Newsletter, 8(1), 6-7.

Tripathi AN, Gotyal BS, Sharma PK, Tripathi RK, Dev Usha, Biswas C, Agarwal PC (2014) Essential Oils: as a Green Biopesticide for Organic Farming. Organic Farming and Management of Biotic Stresses. Biotech Books, New Delhi, India,pp. 548–554.

Tripathi AN, Manjunath M, Chaurasia A., Pandey KK, Singh B and

Gupta Sunil (2019) Evaluation of microbial bio agents against plant diseases and management of plant health in bottle gourd under field condition. In book of abstracts I Vegetable Science Congress on Emerging Challanges in Vegetable Research and Education (VEGCON-2019), Agriculture University Jodhpur, Rajasthan, p208-209.

Tripathi AN, Meena BR and Pandey KK (2019). Evaluation of bio-agents of IIVR strains and new fungicides under nursery condition. In book of Souvenir and abstracts International Conference on plant protection in horticulture: advances and challenges (ICPPH), ICAR-Indian Institute of Horticultural Research, Bengaluru, p 45.

Tripathi AN, Meena BR, Pandey KK and Singh J (2020) Microbial Bioagents in Agriculture: Current Status and Prospects. In: *New Frontiers in Stress Management for Durable Agriculture.* Amitava Rakshit, Harikesh Bahadur Singh, Anand Kumar Singh, Uma Shankar Singh and Leonardo Fraceto (eds). I Edn. Springer Nature, Singapore, Pp. 361-368.

Tripathi AN, Meena BR, Pandey KK, Rai AB, Gupta S and Singh B (2016) Cross infectivity of *Sclerotinia sclerotiorum* on leguminous vegetables. ICAR-IIVR, Vegetable Newsletter, 3 (2), 5.

Tripathi AN, Meena BR, Pandey KK, Rai AB, Gupta S. and Singh B. (2017). Identification and characterization of ripe chili fruit rot pathogen. ICAR-IIVR, Vegetable Newsletter, 4 (1), 5.

Tripathi AN, Pandey KK, Manjunath M, Meena BR, Rai AB and Singh B (2017) Morphological characterization, cross infectivity and chemo-sensitivity of Sclerotinia sclerotiorum isolates towards bio-agent and new molecules of fungicides. Vegetable Science 44 (1): 103-106.

Tripathi AN, Pandey KK, Meena BR, Rai AB, Singh B (2017) An emerging threat of *Phytophthora infestans* causing late blight of tomato in Uttar Pradesh, India. New Disease Reports 35, 14. http://dx.doi.org/10.5197/j.2044- 0588.2017.035.014.

Tripathi AN, Pandey KK, Rai AB and Gupta Sunil (2016) Late blight: An emerging disease of tomato in Eastern Uttar Pradesh. ICAR-IIVR, Vegetable Newsletter, 3 (1), 4-5.

Tripathi AN, Pandey KK, Rai AB, Pandey S and Singh B (2018). Kadduvargiya sabjiyon me tana sraw jhulsa (gummy stem blight) rog ka samanvit prabhandhan. Sabji Kiran, ICAR-IIVR, Varanasi, 12 (1& 2), 111-112.

Tripathi AN, Roy S, Singh AK and Tiwar SK (2021). Prakhetra me jaiv nyantrak *Trichoderma* ki utpadan taknik. *Sabji Kiran*, ICAR-IIVR, Varanasi, 15(1), 72-73.

Tripathi AN, Roy S, Tiwari SK, Pandey KK and Behera TK (2021) Sabji paudhshala hetu jaiv niyantran taknik kea yam. VigyanPragati, 69 (10), 46-61.

Tripathi AN, Sarkar SK, Sharma HK, Karmakar PG (2014). Detection and characterization of roselle stem rot pathogen, *Sclerotinia sclerotiorum* (Lib.) de Bary and its sensitivity towards bioagents. National Symposium on Plant Pathology in Genomic Era, Department of Plant Pathology, Indira Gandhi Krishi Vishwavidyalay Raipur, Chhattisgarh, 8-9.

Tripathi AN, Sharma P, Agarwal PC, Dev Usha, Hazarika BN, Tripathi SK, Singh US, Khetarpal RK, Satpathy S (2013) Aflatoxins: Threat for agricultural trade and food safety. In: Prasad, Ray DP (Eds). Biotechnological Approaches in Crop Protection. Biotech Books, New Delhi, pp. 490–499.

Tripathi AN, Singh D., Pandey KK, Singh J. (2021). Postharvest diseases of leguminous vegetable crops and their management (1 st ed.). Post-Harvest Handling and Diseases of Horticulture produce. CRC Press, Londan, 387-396.

Tripathi AN, Singh RK and Rai A B (2018) Large scale multiplication of important bio-agents for organic farming for vegetable crops. In production, processing and marketing of organic vegetables. ICAR-IIVR Feed the Future India Triangular Training (FTFITT). ICAR-Indian Institute of Vegetable Research, International Training Manual *No. 80,* Pp 190-200.

Tripathi AN, Srivastav K and Singh J (2021). Kenchuakhad Se ugai gayee sabjiyon me jaivik vidhi se Rog Prabandhan. Kenchua khad Utpadan Kaushal vikas karyakram. ICAR-IIVR Training Manual No. 97 Pp.110-113.

Tripathi AN, Srivastav K and Tiwari SK (2020) Sabjiyon ki Paudhshala me Rogon evm Keeton ka Jaivik Prabandhan. SabjiKiran, ICAR-IIVR, Varanasi, 14 (2), 74-75.

Tripathi, A.N. and Bhanu Prakash Singh (2022). Evaluation of seed health of seeds of different vegetable crops. *Vegetable News Letter*, 9 (1),7.

Tripathi, A.N., Sarkar, S.K. and Agarwal, P.C. (2015). Assessment of seed borne fungal infection in conserved seed samples of jute (*Corchorus* sp.) and mesta (*Hibiscus* sp.) germplasm. *Indian Journal of Natural Fibres,* 1 (2): 245-250.

सारांश

सब्जी फसलों में पादप रोगों से 40-60% तक नुकसान होता है। सब्जी फसलें कवक, बैक्टीरिया, वायरस, वाइरॉयड, फाइटोप्लाज्मा और सूत्रकृमि द्वारा होने वाले विभिन्न प्रकार के रोगों के प्रति तुलनात्मक रूप से अधिक ग्राहय होती हैं। कवकीय रोगजनकों जैसे अल्टरनेरिया, एस्कोचाइटा, कोलेटोट्रिचम, डिडिमेला, फोमा, फाइटोफ्थोरा, पाइथियम, राइजोक्टोनिया, स्क्लेरोटिनिया आदि का सब्जियों में प्रकोप होता है। सब्जी बीज उत्पादन के लिए बीज जनित कवक रोग प्रमुख समस्या बन गए है। टमाटर (झुलसा, फ्यूजेरियम मुरझान), मिर्च और मिर्च (एन्थ्रेक्नोज, फाइटोफ्थोरा झुलसा), बैंगन (फोमोप्सिस झुलसा, अल्टरनेरिया लीफ स्पॉट), कुकुर्बिट्स (डाउनी मिल्ड्यू, गमी स्टेम झुलसा, एन्थ्रेक्नोज और सर्कोस्पोरा लीफ स्पॉट), भिंडी (सर्कोस्पोरा लीफ स्पॉट), मटर (पाउडरी फफूंदी, फ्यूजेरियम विल्ट), लोबिया/बीन (एन्थ्रेक्नोज, स्क्लेरोटिनिया स्टेम गलन), कोल क्रॉप (ब्लैक रॉट, अल्टरनेरिया ब्लाइट, डाउनी मिल्ड्यू) आदि रोगजनकों द्वारा माइकोटॉक्सिन के उत्पादन के कारण उन्हें मानव उपभोग और बाजार के लिए अयोग्य बना देती है। सब्जियों के रोगजनकों (रोगों) के सुरक्षित प्रबंधन के लिए रोगजनकों (रोगों) की पहचान और निदान आवश्यक है।