Important Seed-Borne Pathogens

Fungal Seed-Borne Pathogens

Fusarium

Fusarium belongs to family *Nectriaceae* and it is a large genus of filamentous fungus. It is a cosmopolitan soil fungus, and its species are responsible for seed-borne diseases in many crops. *Fusarium* species occur in many economically important plants like cereals, and ornamental plants and cause losses in crop yield.

Distribution

Fusarium has a worldwide distribution and includes vital range of economically important seed-borne fungal pathogens, viz., *Fusarium acuminatum*, *F. avenaceum*, *F. crookwellense*, *F. culmorum*, *F. equiseti*, *F. graminearum*, *F. nivale*, *F. poae*, *F. sambucinum*, *F. sporotrichioides*, *F. anthophilum*, *F. oxysporum*, *F. proliferatum*, *F. semitectum*, *F. solani*, and *F. verticillioides*. Species of *Fusarium* are distributed in different geographic region of world but some species of *Fusarium* are found associated with specific plant species with specific geographic region or climatic zone.

The maximum distribution of *Fusarium* spp. was found in the vascular system. But any other growth stages of the host plants may also be infected by *Fusarium oxysporum*. Among them tomato, tobacco, legumes, cucurbits, sweet potatoes, and banana are highly susceptible to *Fusarium*, but it also infects some other agricultural crops. Vascular wilt is the most important symptoms of *Fusarium* spp. Wilting, chlorosis, necrosis, premature leaf drop, browning of the vascular system, stunting, and damping-off are some other core symptoms of *Fusarium oxysporum*, *Fusarium*

oxysporum is split into divisions called formae speciales. There are over 100 formae speciales divisions with the different races.

Biology

Fusarium sp. comes under the *Sordariomycetes* class of the *Ascomycota* based on the structure of conidiogenous hyphae. Microconidia, macroconidia, and chlamydospores are asexual spores reported from *Fusarium* species. Monophialides and sporodochia produce conidia which are loosely scattered on the mycelium. The microconidia of *Fusarium* are predominantly uninucleate and germinate poorly ranging from 1 to 20%. Comparative to microconidia, the macroconidia reproduce fungus efficiently because they are abundant, multinucleate, and germinate rapidly. The vegetative hyphae of *Fusarium* produce chlamydospores which are accessory spores, result of asexual reproduction (structural modification) and these remain viable in unfavorable conditions. The conidial cell which possesses a thick wall, mainly consisting of newly synthesized cell wall material, may result into chlamydospores due to structural modification. It's function is primarily survival in seed/soil.

Symptoms

Fusarium is popularly known for causing *Fusarium* wilt in many agriculturally important crops. Among them *Fusarium* wilt of banana is caused by fungus known as *F. oxysporum* f. sp. *cubense* (*Foc*).

The starting or primary symptoms occur on leaves and seem like vein clearing of younger leaf, yellowing of the lower leaves, dropping down of lower leaves, stunting of plant, and finally death of the plant. The distinct symptoms can be seen on older plants between the blossoming and fruit maturation stages. Each forma specialis within the species is host-specific and produces different symptoms.

F. oxysporum f. sp. *lycopersici* causes vascular wilt in tomato. The primary symptoms of the disease occur as yellowing of leaves and drooping on one side of the plant. It also causes leaf wilting, plant stunting, browning of the vascular system, and loss of fruit production. *F. oxysporum* f. sp. *melonis* attacks on muskmelon and cantaloupe. It causes damping-off in seedlings and causes chlorosis, stunting, and wilting in old plants. Necrotic streaks can appear on the stems. Apart from wilt disease, *Fusarium* spp. cause many important plant diseases, viz., bakanae disease of rice, head blight of wheat, Panama disease of banana, etc.

Tilletia

Karnal bunt and smut are popularly known diseases of wheat spread all over the world. Infected grain of wheat with Karnal bunt gives smell but infected grains are nontoxic for human beings and animals. Three diseases including common bunt caused by *Tilletia tritici* and *T. laevis*, loose smut caused by *Ustilago tritici*, and flag smut caused by *Urocystis tritici* occur in wheat-growing regions of the world. Another two bunt diseases including Karnal bunt caused by *T. indica* and dwarf bunt caused by *T. controversa* are important diseases and restricted throughout the world and come under quarantine regulations.

Distribution

Karnal or partial Bunt disease of wheat was first reported from Karnal (India) in 1931 so it is called as Karnal bunt. The causal organism of Karnal bunt is *Tilletia indica* Mitra (syn. *Neovossia indica* (Mitra) Mundk.). It is distributed in Northwest India and nearby area of Pakistan and Afghanistan (Wiese 1987). The disease is reported not only from India but also from Iran, Iraq, Nepal (USDA Karnal Bunt Manual 2003), Mexico, the Southwestern United States, and South Africa. Further,

disease was detected in Texas and parts of California and also testified positive with Karnal bunt in shipments from Lebanon and Syria.

Biology

Contaminated seed and farm equipment are the main sources for disease distribution. The disease is also spread through wind to short distance area especially followed by burning of wheat straw by farmers.

Under favorable environmental conditions, teliospore comes in contact with suitable host and by germination produces promycelium. After complete development of promycelium, around 65–180 primary sporidia can be seen. The secondary sporidia develop from bud of primary sporidia and from mycelium of fungal threads. The secondary sporidia are the main infectants responsible for disease development in young plant at flowering stage by ovary wall. The entry of secondary sporidia in host plant is achieved by penetrating through germ tubes. After the penetration, the sporidia come in contact with kernels and replace healthy tissues of kernels with vast number of teliospores. The teliospores remain as inactive spores in soil during harvesting practices and transfer from one field to another by wind and farming tools. These resting teliospores are responsible for further disease development in the next crop season.

Symptoms

Early stage of disease development bunts symptoms cannot be seen, but in severe conditions after disease development, it can be seen on crop, and conspicuous smell can be felt from infected wheat grains. The identification of bunt disease can be done on the bases of morphological study of teliospore and symptoms of infected seeds and by molecular techniques.

Alternaria

The *Alternaria* belongs to family *Pleosporaceae* and comes under the *Ascomycetes* group which has many saprophytic and parasitic fungal species. It is also well-known for its extremely destructive behavior for plant and human beings. *Alternaria* is frequently found in various economically important and cultivated families including Cucurbitaceae, Brassicaceae, and Solanaceae, but cruciferous crops like broccoli, cauliflower (*Brassica oleracea* L. var. *botrytis* L.), field mustard, turnip (*B. rapa* L. (synonym: *B. campestris* L.), Chinese mustard or leaf mustard (*B. juncea*), Chinese or celery cabbage (*B. pekinensis*), cabbage (*B. oleracea* var. *capitata*), rape (*B. campestris*), and radish (*Raphanus sativus*) are highly infected with *Alternaria* comparative to other crop.

Distribution

Species of *Alternaria* have cosmopolitan distribution especially tropical and subtropical region of the world. It has a wide range of disease distribution in various economically important and popular commercially cultivated crops including cereals, legumes, and oilseeds and a large number of post-harvest crops. Generally, early blight of crops is caused by *Alternaria* and its strains and it damages widespread tropical crops.

Biology

Alternaria produces asexual conidia/spores from conidiophores, size ranging from 160 to 200 μm long. The sporulations occur between the range of 8 and 24 °C under aseptic condition, and mature spores develop after 14–24 h. The ideal time and temperature for sporulation are 12 and 14 h and 16 and 24 °C, respectivily. Some environmental factors like moisture, rain, and humidity and time ranging from 9 to 18 h are important requirements for infection for majority of the species.

The seed coats infected with pathogen are primary source for disease or pathogen transport. Wind, water, agricultural tools, and animals are some factors responsible for spores' distribution. After harvesting, the pathogens remain in dormant condition on susceptible weed and other crops which are the major source of *Alternaria* species.

Symptoms

Alternaria causes blight disease resulting in 32–57% average fruit yield loss on crops. Blight is the most common and dominant disease which shows irregular, often circular brown- to dark brown-colored spots on the leaves with concentric lines inside the spots. Generally, small circular spots join together and become large in size and lead to leaf blight. These small spots sometimes can be seen on pods and tender twinges.

Curvularia

Distribution

Curvularia is a facultative plant pathogen which belongs to family *Pleosporaceae* that comes under *Ascomycetes* group. It is a phytopathogenic saprophytic fungus which spreads throughout tropical and subtropical regions and mostly found in soil, air, organic matter, plants, and animals. It was studied that nearly 30 species of *Curvularia* are found in anamorphic states of the *Loculoascomycetes* genera *Cochliobolus* and *Pseudocochliobolus*. The majority of diseases caused by *Curvularia* species have been reported from India and out of the country including the United States, Brazil, Japan, and Australia.

Biology

It is broadly spread all over the world but especially predominated in tropical and subtropical regions. The inoculum surviving in the soil is the primary reason for the

infection that is caused by air-borne conidia and ascospores. The inoculum requires 24–30 °C temperature in aseptic condition for growth, but it will become dead on temperature exposure at 59 °C for 1 min or 55 °C for 5 min. The susceptible condition is required for successful infection when the host plant comes in contact with wet surface for 13 h.

Symptoms

Curvularia species cause discoloration of the aleurone and starch layer, and the hulls become brown. A close association exists between discoloration of glumes, empty glumes, and kernels. When an empty glume dies, severe smudge of the kernels is observed. In favorable conditions, *Curvularia* causes discoloration on rice grains, and a few of them mold the grain. In severe infections, *Curvularia* spp. may cause seedling blight and weakening of the seedling.

Common Seed-Borne Bacterial Pathogens

The most important bean bacterial pathogens transmitted by seeds, *Pseudomonas savastanoi* pv. *phaseolicola*, *Pseudomonas syringae* pv. *syringae*, *Xanthomonas axonopodis* pv. *phaseoli*, and *Curtobacterium flaccumfaciens* pv. *flaccumfaciens*, are widespread and destructive diseases in bean-growing regions.

Following is the list of bacterial pathogens borne in true seeds in important crops:

1. Wheat: *Pseudomonas syringae* pv. *syringae*, *Xanthomonas campestris* pv. *translucens.*

2. Maize: *Pantoea stewartii* subsp. *stewartii*, *Clavibacter michiganensis* subsp. *nebraskensis.*

3. Rice: *X. oryzae* pv. *oryzae, X. oryzae* pv. *oryzicola, Acidovorax oryzae.*

4. Bean: *P. syringae* pv. *phaseolicola*, *Curtobacterium flaccumfaciens* pv. *flaccumfaciens*, *Xanthomonas campestris* pv. *phaseoli*, and *X. fuscans* var. *fuscans.*

5. Soybean: *P. syringae* pv. *glycinea.*

6. Chickpea: *Rhodococcus fascians.*

7. Cereals and grasses: *Rathayibacter* sp.

8. Alfalfa: *C. michiganensis* subsp. *insidiosus.*

Examples of some important seed-borne bacterial diseases are bacterial blight caused by *Xanthomonas oryzae* pv. *oryzae* in rice, basal glume blotch caused by *P. syringae* pv. *syringae* in wheat, Goss's bacterial wilt and blight caused by *Clavibacter michiganensis* subsp. *nebraskensis* in maize, bacterial blight caused by *P. syringae* pv. *glycinea* in soybean, and black rot caused by the bacterium *X. campestris* in crucifers and carrot.

Seed-borne nematodes

Seed-borne nematodes are one of the most important biotic constraints in the crop production worldwide. Nematode diseases associated with seed usually go unnoticed as infected plants are rarely killed. They cause direct damage to the seed which may be internal or may occur as seed infestation. Nematodes are migratory or sedentary parasites which evolve from ectoparasitic and endoparasitic associations with plants and are found in rhizospheric soil around the root.

Seed infestation by nematodes does not produce any specific symptoms on seed, but in those that occur as endoparasites, the floral structure may be modified into a seed gall (*Anguina* spp.), may produce symptoms such as discolouration of testa in

groundnut (*Ditylenchus destructor*), or may be symptomless as in paddy kernels infected by *Aphelenchoides besseyi*.

There are several nematode species causing seed infection, but the major seedborne or associated nematodes belong to the genera Anguina, Ditylenchus, Aphelenchoides, Pratylenchus, and Bursaphelenchus (Rhadinaphelenchus) cocophilus. Some groups of nematodes show host specificity and these are supposed to have co-evolved along with their hosts. Hence, sometimes it becomes important to have knowledge of the host species and the species of nematode. There is difference in portion of the seed infected, but in general their mechanism and adaption are same belonging to associated genera (Table).

Table: List of major genera of nematodes associated with seed.

S. No.	Nematodes	Part of seed infected	Host plant
1.	*Anguina tritici*	Seed galls	*Triticum aestivum, Avena sativa, Secale cereale*
2.(a)	*Ditylenchus destructor*	Hull, seed coat, and surface	*Arachis hypogaea*
			Solanum tuberosum
2.(b)	*Ditylenchus dipsaci*	Bulbs, tubers, and rhizomes	*Allium cepa*
2.(c)	*Ditylenchus angustus*	Seed	*Oryza sativa*
3.	*Aphelenchoides besseyi*	Beneath hull	*Oryza sativa*
4.	*Pratylenchus brachyurus*	Hull	*Arachis hypogaea*
5.	*Bursaphelenchus (Rhadinaphelenchus) cocophilus*	Seeds, seedlings, and nut husk	*Cocos nucifera*
			Phoenix dactylifera

Seed-Borne Viruses and Phytoplasma

Till date, there are more than 200 plant viruses, viroids and phytoplasma reported to be seed-transmitted in different crop plants. Moreover, more than 60 viruses infecting leguminous crops are known to be seed-transmitted.

Economic Impact

Plant viruses cause enormous crop losses in different agricultural or horticultural crops. The entire crop loss due to plant viruses is determined based on the stage of viral infection, severity of infection, reaction of the hosts and conducive environment for its multiplication in the system. Estimation of the crop loss has to be monitored under controlled conditions by mechanical transmission of the virus along with the healthy control and under natural conditions. There are many reports on seed-transmitted viruses causing economic losses to different crops worldwide (Table).

Table 14.1 Distribution of seed-transmitted viral diseases of different crops worldwide with their causal virus, genus and family

Crop	Disease	Causal virus (acronym)	Genus (family)	Country	References
Legumes					
Soybean	Bud blight	*Tobacco ringspot virus* (TRSV)	*Nepovirus*	USA, China and India	Hill (2003) and Frison et al. (1990)
	Dwarf	*Soybean dwarf virus* (SbDV)	*Luteovirus*	Japan, Indonesia, Africa, Australia and New Zealand	Hartman et al. (1999)
	Vein necrosis	*Tomato spotted wilt virus* (TSWV)	*Orthtospovirus*	USA	Groves et al. (2016)
	Leaf curl	*Tomato yellow leaf curl virus* (TYLCV)	*Begomovirus*	Korea	Kil et al. (2017)

Groundnut	Stem necrosis	*Tobacco streak virus* (TSV)	*Ilarvirus*	India	Reddy et al. (2001)
	Clump	*Peanut clump virus* (PCV)	*Pecluvirus*	Pakistan and West Africa	Bragard et al. (2008)
		Indian peanut clump virus (IPCV)		India	Reddy et al. (2008)
	Mottle	*Peanut mottle virus* (PeMoV)	*Potyvirus*	China, Georgia and India	Reddy and Thirumala Devi (2003)
	Stripe	*Peanut stripe virus* (PStV)		China and Georgia	Lynch et al. (1988) and McDonald et al. (1998)
	Yellow mosaic	*Cucumber mosaic virus* (CMV)	*Cucumovirus*	China and Argentina	Xu and Barnett (1984)
Common bean	Common mosaic and black root	*Bean common mosaic virus* (BCMV)	*Potyvirus*	Europe, India, Peru and Spain	Morales (2003), Sharma et al. (2008), and Ferreira et al. (2012)
		Bean common mosaic necrosis virus (BCMNV)		Eastern Africa, Dominican Republic Haiti and Tanzania	Morales (2003) and Chilangane et al. (2013)
	Mosaic	*Cucumber mosaic virus* (CMV)	*Cucumovirus*	Chiley, Iran and Turkey	Morales (2003) and Schwartz et al. (2005)

Crop	Disease	Causal virus (acronym)	Genus (family)	Country	References
Cowpea	Mosaic	*Cowpea aphid-borne mosaic virus* (CABMV) and *Bean common mosaic virus*- Blackeye cowpea mosaic strain (BCMV-BICM)	*Potyvirus*	Ghana, West Africa, Nigeria and Burkina Faso	Bashir and Hampton (1996) and Salem et al. (2010)
	Mosaic	*Cowpea mosaic virus* (CPMV) and *Cowpea severe mosaic virus* (CPSMV)	*Comovirus*	Most of the cowpea producing countries	Bashir and Hampton (1996) and Salem et al. (2010)
	Mosaic	*Southern bean mosaic virus* (SBMV)	*Sobemovirus*		
	Stunt	*Cucumber mosaic virus* (CMV) and *Bean common mosaic virus*- Blackeye Cowpea mosaic strain (BCMV-BICM)			
	Mild mottle	*Cowpea mild mottle virus* (CMMV)	*Carlavirus*		
		Cowpea mottle virus (CPMoV)	*Carmovirus*		
Pea	Mosaic	*Pea-seed-borne mosaic virus* (PSbMV)	*Potyvirus*	Czech Republic	Kraft and Pfleger (2001)
		Bean yellow		Syria, Egypt,	Kraft and

		Bean yellow mosaic virus (BYMV)		Syria, Egypt, Italy and Libya	Kraft and Pfleger (2001) and Makkouk et al. (2012)

Crop	Disease	Causal virus (acronym)	Genus (family)	Country	References
Faba bean	Mosaic and necrosis	*Bean yellow mosaic virus* (BYMV)	*Potyvirus*	Egypt, Iraq, Sudan, Israel, Italy, Lebanon, Libya, Morocco, Syria, Tunisia, Greece and Turkey	Makkouk et al. (2012) and El-Bramawy and El-Beshehy (2012)
	Mottle	*Broad bean mottle virus* (BBMV)	*Bromovirus*	Morocco, Sudan, Tunisia, Syria, Egypt and Algeria	Makkouk et al. (2012)
Lentil	Mosaic and mottle	*Pea-seed-borne mosaic virus* (PSbMV)	*Potyvirus*	Algeria, Egypt, Ethiopia, Iran, Iraq, Jordan,	Kumari et al. (2009)

				Pakistan, Syria, Tunisia and Turkey	
		Cucumber mosaic virus (CMV)	*Cucumovirus*	Australia, Ethiopia, India, Iran, Nepal, New Zealand, Pakistan and Syria	Kumari et al. (2009)