Chapter 3
Integrated Fungal Foliar Diseases of Arid Legumes: Challenges and Strategies of Their Management in Rain-Fed Areas

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3.1 Introduction

Grain legumes play a major role in improving food and nutritional security of farmers and populations, covering up to 45% of arid and semiarid regions of the world (Sprent and Gehlot 2010). Some of the globally important grain legumes which are grown worldwide and economically important are chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik), cowpea (*Vigna unguiculata* (L.) Walp), and faba bean (*Vicia faba* L.) (Cernay et al. 2016; Raseduzzaman and Jensen 2017). These legumes are severely damaged by numerous plant pathogens from bacteria to fungi and viruses to nematodes causing economic losses globally (Jones et al. 2013). Among these pathogens, fungi are the largest group that affects all parts of the plants, majorly foliar parts. Fungal foliar diseases such as *Ascochyta* blight (*Ascochyta rabiei*) and *Botrytis* gray mold (*Botrytis cinerea*) affect chickpea (*Cicer arietinum*). In lentils, *Ascochyta* blight is caused by *Ascochyta lentis* and rust is caused by *Uromyces viciae-fabae* Pers. Anthracnose (*Colletotrichum lindemuthianum* Sacc. & Magn.) and *Cercospora* leaf spot (*Cercospora canescens* Fellis & Martin and *Cercospora cruenta* Sacc.) affect cowpea, respectively. Chocolate leaf spot (*Botrytis fabae* and *B. cinerea*) and rust (*Uromyces viciae-fabae*) affect faba bean (Girish et al. 2019). Challenges in sustainable management are lack of understanding of integrated pest management while adopting biopesticides in underdeveloped countries conquer the disease and are not effective as chemical fungicides and hence the farmers are not willing to use the products (Parsa et al. 2014; Peshin et al. 2009; Vandana et al. 2017). The integrated disease management (IDM) of legumes in a particular area depends upon the genetic resistance and other components of disease management (Coakley et al. 2002; Isman 2000). IDM program lies in identifying, evaluating, merging, and locating distinct components (D'Mello et al. 1998;

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Nel et al. 2007). This chapter emphasizes on the globally important arid and semi-arid legumes, affected by important fungal foliar diseases, and strategies of IDM for the control of fungal diseases. Approaches to sustainable management including cultural and physical practices, exploitation of host resistance, and protection with a synthetic fungicide are also discussed in the chapter.

3.2 Chickpea

Chickpea is a staple grain legume, the most prevalent food legume in the world. It serves as a major source of human diets rich in nutrients (protein) and high-quality crop residues for animal feed as well. Some of the crucial facets of chickpea are to maintain the fertility of soil via biological nitrogen fixation, furthermore in contributing to the sustainability of cropping structures by approaching practice like cereal-legume rotations. The significance of chickpea among temperate pulses is its tolerance to heat and drought in low fertility soils. Some of the important diseases affecting chickpea crop are:

3.2.1 Ascochyta *Blight (*Ascochyta rabiei*)*

Ascochyta rabiei comes under the most devastating fungal diseases of chickpea in numerous countries (Pande et al. 2005), favoring disease development and spread particularly by environmental conditions (cool and wet weather).

3.2.1.1 Diagnosis and Epidemiology

The fungal pathogen outbreaks parts above the ground of the plant. Fungi thrive on infected seeds, crop residues, and volunteer seedlings starting from one growing season to the next. When conditions are favorable and the prime source of inoculum is a seed, some dark brown lesions develop in the stem. When it comes to the air-borne spores, initial indications emerge as tiny necrotic specks on aerial parts of the primordial leaves. These specks under cool and wet conditions rapidly become enlarged and cohere, with the blighted portions having pycnidia formed all over the plant. In a susceptible culture, the necrosis progressively grows down, thereby killing the infected plant. Lesions are inversely ovate to extend and bear pycnidia on the stems and petioles. Generally, there is a breakage in stems and petioles due to engirdle. The round lesions develop on pods with some pycnidia, generally arranged in concentric rings, where the pod wall is penetrated by a fungus, infecting the seed on which lesions develop. Crop infection may emerge from seed-borne inoculum and from conidia of rain-splashed or windborne ascospores from infested parts. It was displayed that the teleomorph (the sexual reproductive stage of any fungus of phyla

Ascomycota and *Basidiomycota*) has a crucial portion in the epidemiology of the infection and played important role in controlling the disease in Spain and the United States (Kaiser et al. 2011).

3.2.1.2 Control

Disease control can include approaches such as burying the harvest debris, abolition of seed-borne inoculum, and establishing disease-resistant varieties. ICARDA and ICRISAT released numerous blight-resistant cultivars (Nene et al. 2011) which involve methods such as seeding blight-free seed, application of foliar fungicides and seed treatments and rotation of crop for 3 years, controlling diseased debris, and finally implanting blight-resistant varieties.

*3.2.2 Botrytis Gray (*Botrytis cinerea*)*

Botrytis grey mould is the common plant diseases in India, Nepal, Pakistan, and Bangladesh which is caused by *Botrytis cinerea*, which is reported to reduce yields in Australia and Argentina as well (Pande et al. 2006). Favorable conditions for the pathogen can substantially lead to major yield loss (Rashid et al. 2014).

3.2.2.1 Diagnosis and Epidemiology

A minimum of five diverse pathogen types of *B. cinerea* were identified (Kaiser et al. 2011). Furthermore, studies in pathogenic variability are mandatory. The inceptions of infection take place in the lower portions of the infected plant initially and later, under favorable condition, extend to the upper leaves. Often, there is a development of soft rot, and fungus sporulation can be noticed at the plant basal part in the seedlings which were seed infested with *B. cinerea.* Plant parts cultivated symptoms like dark-colored lesions mainly shielded with moldy fungal development. Changes such as complete engirdling of stems by lesions and breaking off of tender branches at the site where gray mold causes decomposition can be observed. Damaged leaves and flowers eventually turn into a decaying mass, and pods almost disappear or left with less quantity, withered spores (having lost all moisture). Immature seeds develop grayish-white mycelium. *B. cinerea* has a broad range of host, there is almost always a presence of the inoculum in the environment, and it can survive with other crops and weeds. Kaiser et al. (2011) conducted some experiments in a glasshouse, where they found that the fungus is being potential on 8 different crop species and 21 weed types. Feasibility of seed-borne source greatly reduces when kept in room storage. However, there is a prompt diminution in the sustainability of the fungus throughout stowage. The disease is mainly favored by moist and moderate temperatures. The respective significance of seed-borne inoculum and additional causes needs to be explored in different parts.

3.2.2.2 Control

Voluminous lines of chickpea with moderate resistance to gray mold were found although lines of resistance with increased levels have not been found. They found 22 lines with valuable resistance out of 8500 accessions evaluated. Despite a huge degree of flower infection, numerous chickpea lines produce good yields (Kaiser et al. 2011). The severity of gray mold can be reduced by the late sowing of chickpeas, but it leads to reduced yields in normal years (Kaiser et al. 2011). Gray mold can be efficiently reduced by seed treatment trialed by three sprays of carbendazim (Kaiser et al. 2011). The effectiveness of foliar sprays of vinclozolin was reported as well (Kaiser et al. 2000). Seed treatment with the spraying of triadimefon, carbendazim + thiram, mancozeb, or triadimefon was useful in checking seed-borne infection (˃94%) (Kaiser et al. 2011) followed by observation 50 days post-sowing or at the advent of indications which resulted in comprehensive control of both primary and secondary infections. However, at present, disease resistance at a high level is not found in chickpea cultivars. Therefore, moderately resistant cultivars are necessary to be developed in combination with an integrated disease management program with critical chemical use, and improved cultural procedures appear to minimize crop loss devastated by gray mold.

3.3 Lentil

Lentil is regarded as one of the important legumes considering its nutritive value. It is an outstanding source of molybdenum and folate and also serves as a rich source of copper, phosphorus, manganese, and dietary fiber (Hall et al. 2017). It serves as a staple food in countries like India, Canada, Turkey, the United States, and Nepal. According to the USDA National Nutrient Database, 353 calories can be produced from 100 g of raw lentil (Agriculture 2014). Lentils are rich in water (8%), carbohydrates (63%), dietary fiber (11%), protein (25%), and fat (1%). They are also rich in phosphorus (40% DV), iron (50% DV), zinc (35% DV), folate (120% DV), thiamin (76% DV), pantothenic acid (43% DV), and vitamin (42% DV (Faris et al. 2013).

*3.3.1 Rust (***Uromyces viciae-fabae** ***Pers.)***

One of the serious diseases of lentils is caused by rust (*Uromyces fabae*), which is particularly damaging the crops in countries like India, Chile, Pakistan, Ethiopia, Morocco, and Ecuador (Kaiser et al. 2011).

3.3.1.1 Diagnosis and Epidemiology

Environmental conditions (temperatures varying between 20 and 22 °C and wet weather) favour the initial infection and disease development, resulting in crop loss. All the green plants, including plant parts and pods, are infected. Early symptoms of yellowish-white pycnia (spermatogonia) and aecia (individually or in small groups) appear on the undersurface of pods and leaflets and eventually turn brown. Dark brown to black teliospores are observed to be developed on leaves and on stems and petioles. Crop genera including *Lathyrus*, *Lens*, *Pisum*, and *Vicia* are infected by the pathogen majorly. Before the establishment of a favorable and effective pathogenic relationship, there is a necessary association between the pathogenic cell surfaces and its host. Following the contact between the two faces, pre-penetration is a basic necessity for the events that lead to disease development (Negussie and Pretorius 2012). Many pathogenic fungi such as *U. viciae-fabae* produce substances that are generally present in the extracellular matrix which facilitate adhesion of gremlins and ungermlins spores.

Moreover, to extracellular matrix materials, adhesion pads of germinating urediniospores recognized to aid in the addition to the spores on the surface of the host by intensifying the part of interaction for substratum (Negussie and Pretorius 2012). The fungus thrives on infested lentil debris from season to season via teliospores. The diseased debris, when mixed with seed, became infected (Negussie and Pretorius 2012). During the growing season, aeciospores have a vital role in spreading the infection.

3.3.1.2 Control

Numerous approaches are attempted to control the disease which includes field sanitation, crop rotation, seed treatment, and use of foliar fungicides (Nene et al. 2011), and most resistance variety (Kaiser et al. 2011). ICARDA identified novel sources of rust resistance to one or more diseases by screening lentil germplasm in various parts of the world, namely, in Ethiopia, Morocco, and Pakistan, where rust epidemics are frequent. There have been several lines that have moderate resistance. Seed treatment with diclobutrazol compels in annihilating seed-borne inoculum effectively (Nene et al. 2011), and it was also reported with the efficiency of foliar sprays with mancozeb. However, some new inputs in this area of research are required to control this disease.

3.3.2 Ascochyta *Blight (*Ascochyta lentis*)*

Ascochyta blight caused by *Ascochyta lentis*, is one of the most devastating fungal diseases that restrains lentil production. It was first reported from the USSR (Nene et al. 2011).

3.3.2.1 Diagnosis and Epidemiology

A favorable environmental condition such as cool and wet weather leads to disease development and spread of *A. lentis*. It is a seed-borne disease that affects all the aboveground parts of the host plant, creating tiny, spherical gray- to dark-colored lesions along with the dark margins in the vicinity of lacerations on the leaflets. Tiny dark brown to black pycnidia appear in the abrasions on leaflets and pods. Pedersen et al. (1994) reported that although under rain-splashed condition, it leads to conidia dispersion, conditions such as wetness periods of 1–2 days will lead to infection under favorable temperature (10–15 °C). The dispersion of pathogens may also take place via wind-blown infected leaflets and seeds. The fungus thrives in crop debris. Disease epidemiology is needed to be investigated by researchers.

3.3.2.2 Control

The strategies for controlling *Ascochyta* blight in economical and sustainable ways can be via resistance breeding and cultural practices. Practices including crop rotation, early seeding for evasion of damp weather at harvest, and employing disease-free seed can be applied to minimize crop losses (Nene et al. 2011). Numerous fungicides are evaluated to control seed-borne infection with thiabendazole, benomyl, carbathin, and carbendazim having effective manifold degrees.

3.4 Cowpea

Cowpea (*Vigna unguiculata*) is a widely adapted legume. Cowpea has important nutritional content; thus, it is widely consumed by millions of people. The crop is cultivated in warm regions of the world on around seven million hectares (Adebanjo and Bankole 2004). Cowpea is produced in Asia, in North America (southeastern and southwestern regions), and largely in semiarid northeastern Brazil.

*3.4.1 Anthracnose (***Colletotrichum lindemuthianum** *Sacc. & Magn)*

Cowpea is prone to outbreak by several pathogens such as anthracnose from seeding to harvest affected by *Colletotrichum lindemuthianum* (Saccardo and Magnus) Briosi and Cavara, which is first recorded in Nigeria in 1969 (Adebanjo and Bankole 2004). Anthracnose causes a 50% yield loss in cowpea under wet and damp conditions in the regions ranging from Nigerian rainforest belt to other parts of Nicaragua; Eastern, Western, and Southern Africa; and Brazil (Williams 1975).

3.4.1.1 Diagnosis and Epidemiology

The disease is prompted to spread under cool, wet weather and particularly damage monocropped cowpeas and affect all aboveground plant parts. Individual lesions vary in shape, generally, from biconvex to circular, and color, turning tan to dark. Lines with high susceptibility can develop lesions that spread largely in number, rapidly leading to coalescing stems and twigs and petioles engirdle. Later, they appear almost completely brown. Resistant lines appear to have relatively small narrow lesions than hypersensitive lines which range from tiny necrotic flecks to shiny reddish-brown lenticular lesions of 5 mm long without sporulation. About 40% of the pathogen is seed-borne in cowpea (Adebanjo and Bankole 2004). Reduction of 35–50% in grain yield of a highly susceptible line has been measured in a monocrop culture when introduced with the disease at an initial stage during crop growth (Adebanjo and Bankole 2004). Nonetheless, the disease breakthrough is taking a relatively prolonged time in mixed-cropped cowpeas.

3.4.1.2 Control

The most endeavoring approach to control the disease is the utilization of host plant resistance. The cowpea germplasm is collected and screened at IITA where two types of resistance have been identified: (1) hypersensitive reactions make cowpea lines functionally immune, and (2) field resistance allows less or null anthracnose development in nurseries. Nature along with inheritance of this resistance is studied at IITA to produce cowpea with varying degrees and high level of stable resistance to anthracnose.

*3.4.2 Cercospora Leaf Spot (***Cercospora canescens** *Fellis & Martin and* **Cercospora cruenta** *Sacc)*

Cercospora leaf spot is a foliar fungal disease that affects a vast number of legumes including cowpea. *Cercospora canescens* and *Cercospora cruenta* (Williams 1975) both cause *Cercospora* leaf spot. They cause severe loss of yield of <40% in cowpea. Although there are not only a variety of resistant lines but also susceptible ones, there is a necessity to identify suitable varieties for cultivation (Booker and Umaharan 2007).

3.4.2.1 Diagnosis and Epidemiology

The initial symptom of *Cercospora* leaf spot in cowpea is the development of tiny, light-colored spot (almost yellow) which later turned to bronze and then dark grayish circular spot. The fungus produces windborne spores in bulk on the abaxial surface of leaf which gives the spots a gray to dark powdery appearance. Symptoms are not usually observed during flowerin4g time. *C. cruenta* occurs in the leaf with more intensity, as it occurs in all seasons when the susceptible lines are planted. Both species are found to be sporulating on pods as well, favored by wet weather (Ratnadass et al. 2012). Yield reductions of cowpea grain attributed by *C. canescens* and *C. cruenta* are about 20% and 40%, respectively, by IITA (1973) (Vaghefi et al. 2018).

3.4.2.2 Control

Crop practices such as intercropping can be applied which includes planting cowpeas in alternate rows along with another suitable nonlegume crop, such as maize, which can limit or eradicate the spread of disease within a field. Chemical approaches include the fungicide's utility to control disease outbreaks when favorable conditions enable disease establishment. The disease develops on older leaves, but early crop survey is difficult to monitor due to complication in distinguishing symptoms from other types of damage. Mancozeb is applied with a maximum of 2–3 applications subsequently after crop flowering and pod development per planting season (Devasirvatham et al. 2012).

3.5 Faba Bean

Faba bean (*Vicia faba* L.) is another important legume seed rich in protein which can adapt to most of the European climatic conditions. Several faba bean cultivars are characterized by varying amount of diets of nutritional value which contain high and/or reduced levels of tannins and a combination of high or low levels of vicine and convicine (VC) (Crépon et al. 2010). This nutritional value was examined in ruminants and monogastric animals. Faba bean has common usage as a staple food in many emerging countries including countries of Asia and Africa (Gago et al. 2014).

*3.5.1 Chocolate Leaf Spot (***Botrytis fabae** *and* **Botrytis cinerea***)*

Chocolate leaf spot of faba bean is caused by *Botrytis fabae* and *B. cinerea*. The disease affects many parts of the world, reducing faba bean yields (Sahile et al. 2008). Serious epidemics were reported in the UK, Tunisia, and Syria (Nene 2003). Fifty percent of faba bean yield loss has been reported in Egypt which is due to chocolate leaf spot and rust diseases, occurring regularly together (Jensen et al. 2010).

3.5.1.1 Diagnosis and Epidemiology

Generally, symptoms include brown-colored spots on the leaves, strips on the stems and petioles, comprehensive darkening of the infected plant, and ultimately death of the infected plant (Motilal and Sreenivasan 2013). The following symptoms are linked to considerable yield losses during extended rainy periods. The age of faba bean influences the severity of chocolate leaf spot (Plantegenest et al. 2007). When observed under artificial conditions, relatively 7-week-old plants had shown more severe disease development than 2-week-old plants. The optimum temperature for infection is around 20 °C and relative humidity is 85% (Nene et al. 2011).

3.5.1.2 Control

The method of breeding disease-resistant cultivars is mostly practiced. Two-cycle procedure has been followed at ICARDA (Nene et al. 2011). In the first cycle, a broad mixture of *B. fabae* isolates with germplasm lines was evaluated, which were collected from leaves of naturally infected plants from the local susceptible cultivars of Syria (Sari et al. 2018). A couple of coalesced-sporulating lesions were developed in the resistant lines, which were detected in the first cycle and then mixed with the isolates collected from such abrasions. Isolates were later eventually inoculated back in the post-screening cycle to the progenies of the resistant lines identified in the first cycle. Subsequently, the outcome of these screenings gave three lines identified as possessing wide-based and stable resistance (Davidson et al. 2016; Sari et al. 2018).

*3.5.2 Rust (***Uromyces viciae-fabae***)*

The rust occurring in most faba bean-growing areas is triggered by *Uromyces viciae-fabae* (syn. *U. fabae*). It is considered to be the most severe constraint of faba bean in Egypt and is conjoint all over the Mediterranean province. Rashid and Bernier (1991) reported faba bean losses of up to 50%.

3.5.2.1 Analysis and Epidemiology

Rust of faba bean is homoecious and two stages are commonly evident: uredial and teleuto. The development of red pustules occurs on either leaves, stems, or petioles, which exhibited small circles. However, the teleutopustules arise on the leaves, and they are commonly present on the stems. They appear to be brown to black. The rust in faba bean crops results in defoliation. The pathogen is also known to infect pea, lentil, and wild-cultured species of *Vicia* and *Lathyrus*. And detailed epidemiological studies are necessary (Eshetu et al. 2018; Hanounik and Hawtin 2011; Zhang et al. 2019).

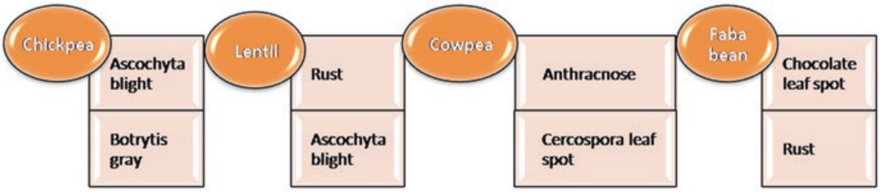

Fig. 3.1 An overview of legumes mentioned in the chapter along with their fungal foliar diseases

Table 3.1 Fungal diseases of legumes and their causal organisms

Sl. no.	Legumes	Fungal diseases	Disease-causing agent	References
1.	Chickpea	*Ascochyta* blight	*Ascochyta rabiei*	Pande et al. (2005)
		Botrytis gray mold	*Botrytis cinerea* Pers. ex Fr.	
2.	Lentil	Rust	*Uromyces viciae-fabae* (Pers.) Schroet	
		Ascochyta blight	*Ascochyta lentis* Bond & Vassil	
3.	Cowpea	Anthracnose	*Colletotrichum lindemuthianum* (Sacc. & Magn.)	
		Cercospora leaf spot	*Cercospora cruenta* (Sacc.)	
4.	Faba bean	Chocolate leaf spot	*Botrytis fabae* and *B. cinerea*	Nene et al. (1988)
		Rust	*Uromyces viciae-fabae*	

3.5.2.2 Control

Practical methods can be applied by utilization of resistant cultivars. There is still an ongoing work at ICARDA and in Canada, where many lines were identified to be resistant. When tested via international nurseries, most of these culture lines were evident with only location-specific resistance. The exceptional case is the resistance of BPL 1179–1 (in Syria, Egypt, and Canada) (Cetin et al. 2002) (Fig. 3.1 and Table 3.1).

3.6 Disease Management of Fungal Foliar Disease

Among the paramount food legumes that are grown globally, the one found in cool season is *Cicer arietinum L.* (chickpea), *Lens culinaris* Medik. (lentil), and *Vicia faba* (faba bean), whereas the one found in warm season is *V. unguiculata* L. (cowpea). Organic pressure markedly minimized the yield of those legumes noticeably. Fungi and viruses are the massive deteriorating factors that affect plants at different growth phases of the legumes (Chen et al. 2006; Ghanem et al. 2015; Walley et al. 2007). Foliar diseases like gray mold and *Ascochyta* blight spawned via varieties of

Botrytis and *Ascochyta* are of vast significance to faba bean, lentil, and chickpeas. In lentil, the genus *Stemphylium* induces foliar disease and in cowpea, *Septoria* species gives rise to leaf spots. Based on published reports, it is found that approximately 45 viruses infect legumes worldwide, but only a few are of economic threat with esteem to certain regions (Gaur et al. 2012; Muehlbauer et al. 2006; Rodda et al. 2017).

In this chapter, a great effort has been made to mark the management of foliar disease of food legumes in both seasons. A successful integrated disease management scheme for economically prime foliar diseases of cowpea, chickpea, faba bean, and lentil has been explored with an allusion to the investigation results on biology, pathogen, and etiology. Integrated disease management strategy (IDM) is the process in which legumes are safeguarded from the yield-reducing consequences of the infectious agent and providing the after commercial insignificance. In this particular system, a discrete constituent of disease controlling plant resistance, backwoods practices, sensible use of fungicides, etc., have to be specific or complementary.

3.6.1 Foliar Disease Management of Food Legumes

Throughout research and development, the prime emphasis to inhibit legume infections is laid upon host resistance and chemical management. The principle of IPM (integrated pest management) has been taken into consideration by IDM (integrated disease management) (Abdullah et al. 2015). The IDM of legumes in a particular area depends upon the genetic resistance, in addition to other components of disease management. Based on the environment, IDM may require a lot of or different components to inhibit foliar diseases (Hema et al. 2014).

In the production of food legumes, the elements of IDM are cataloged in this fashion:

- A host plant resistance
- Disease pressure
- Biotic control
- Agronomic practices

3.6.1.1 Cool Season Legumes

Chickpea The most common foliar diseases in chickpea are *Ascochyta* blight and *Botrytis* gray mold (BGM). This decrepitude was appraised by various workers. Chickpea diseases and their management have been discussed in detail by Varshney et al. (2012). IDM practices are economically vital in potent control of AB (*Ascochyta* blight) and BGM (*Botrytis* gray mold). According to studies in specific areas, several provenances of reluctance to AB were found and the developed genotypes aid to grow the yield during winter in Mediterranean provinces, resulting in the twofold construction potential of chickpeas. And under a high disease pressure, a sufficient level of genetic resistance to BGM is not handy in the cultivated genotype (Tribe et al. 2006). Therefore, the use of handy management options by IDM is vital to mitigate the disease and reduce yield losses.

A union of a fairly resistant type and two chemicals, one during the seedling period and the other at early podding period, issued the best efficient turf control for AB in Syria and Australia (Owati et al. 2017). An IDM package for AB management was initiated by ICARDA in alliance with the Syrian national program. A higher chickpea yield using local variety without other methods was observed with this package. Agronomic and ethnic management of BGM has been exhibited in several countries like India, Bangladesh, and Nepal (Davidson and Kimber 2007; Schreinemachers et al. 2015; Varaprasad et al. 2011; Yadav et al. 2010).

IDM practices for location-specific AB include:

- The seed used that must be free of pathogens
- Treatment of seed with fungicides
- Crop rotation practices
- Deep plowing for burying crowded debris
- Use of disease-resistant genotypes

Lentils The economically vital foliar diseases of lentil are *Ascochyta* blight and rust. *Ascochyta* blight is caused by *A. lentils* producing conidia. It involves the use of resistant cultivators, aiding seed, and seed analysis by foliar spray. It can be maintained by the application of fungicides (Peever et al. 2004). Lentil rust is fostered by *Uromyces viciae-fabae* (Pers.) de Bary, which is an atrocious fungus. The disease arises in the early podding phase as aecia and then into secondary aecis which rapidly shows up a little delay in crop season followed by evaluation of Telia. Integrated management of rust controls volunteer plants in summer and infected lentil debris. It includes the use of clean seeds, suitable fungicide treatment, and host plant resistance. Various rust-resistant cultivators are deployed in different countries, with resistance at CARDIA, Syria, and India (Ammar et al. 2017).

Faba Bean The vital diseases of faba bean are chocolate leaf spot and rust. Another paramount disease of faba bean is brown rust which is spawned by fungus *Uromyces viciae-fabae* Schroet (Mahuku et al. 2016). For controlling the foliar disease of faba bean, the IDM strategy comprises the usage of the disinfected seed, avoiding the spread of disease too quickly, and pursuing crop rotation. In order for the spray program is to be fruitful, regular crop monitoring is crucial. Fungicide application timing depends on the level of disease observed. When high chocolate spot pressure occurs, carbendazim is used, and when rust or *Ascochyta* blight is the problem, then chlorothalonil or mancozeb is used (Varaprasad et al. 2011).

Chocolate spot disease is spawned by *Botrytis fabae*. Initially, chocolate spot occurs on leaves, stem, flowers, etc. as small reddish-brown circular spots. The spot then turned into a gray dead center with a red-brown margin. This disease kills flowers and stems. When the disease spread under favorable conditions, it causes severe defoliation, flower drop, and plant death. The major component of disease management includes resistance because cultural practices and fungicides only give partial crop protection. To take the benefits of high priced fungicides, the faba bean must be grown in early seasons. Chocolate spot control and faba bean yield can be increased by using vinclozolin 50WP, once every 2 weeks. For better management of this disease, different types of fungicides are used such as mancozeb, chlorothalonil, carbendazim, and procymidone (Elliott and Whittington 1979; Noorka and El-Bramawy 2011).

Rust is spawned by *Uromyces viciae-fabae* Pers. Schroet. This rust completes its entire life cycle on faba bean itself. It infects many species. *Uromyces fabae* is short, whitish, and cup-shaped (Barilli et al. 2014).

To reduce the inoculums and avert the disease and future pollution, numerous cultural methods such as suitable plant spacing, appropriate crop rotation, and elimination and burning of crop debris are employed (Sparkes 2016). Field sanitation is vital for reducing losses from faba bean rust. To reduce the chances of primary infection, elimination of infected plant debris and faba bean rotation with nonhost crops play a vital role (Lemke et al. 2007; Rótolo et al. 2015; Wesche et al. 2012). Several control measures are taken to minimize crop losses like the application of mancozeb (0.2%), bayleton (0.05%), and calixin (0.2%) which are fungicides that control pathogenic diseases. The triazole fungicides provide excellent control when applied 72 hours after inoculation. Foliar sprays of mancozeb or chlorothalonil and copper product are valuable in controlling at the time of disease occurrences by a chocolate spot in the same field (Godoy et al. 2016; Hartman et al. 2011) (Fig. 3.2).

3.6.1.2 Warm Season Legume

Cowpea It is the most important legume. *Cercospora* leaf spot, cowpea golden mosaic, and cowpea aphid-borne mosaic are likely of commercial significance. In growing areas of cowpea, *Cercospora* leaf spot is observed. The two most critical diseases in cowpea are cowpea aphid-borne mosaic and cowpea golden mosaic virus. Under field condition, the virus-infected seed gives the basic inoculums, and aphids are accountable for the ancillary extent of the disease. ELISA is one of the important methods for detection of both the seeds and the plant tissue for seed certification project (Nautiyal 2002).

3.7 Sustainable Management of Fungal Foliar Disease

Sustainable management can be defined as a long-term plan of an organized system of plant production practices that will satisfy the present human needs without compromising the economy of future generations and also enhancing environmental

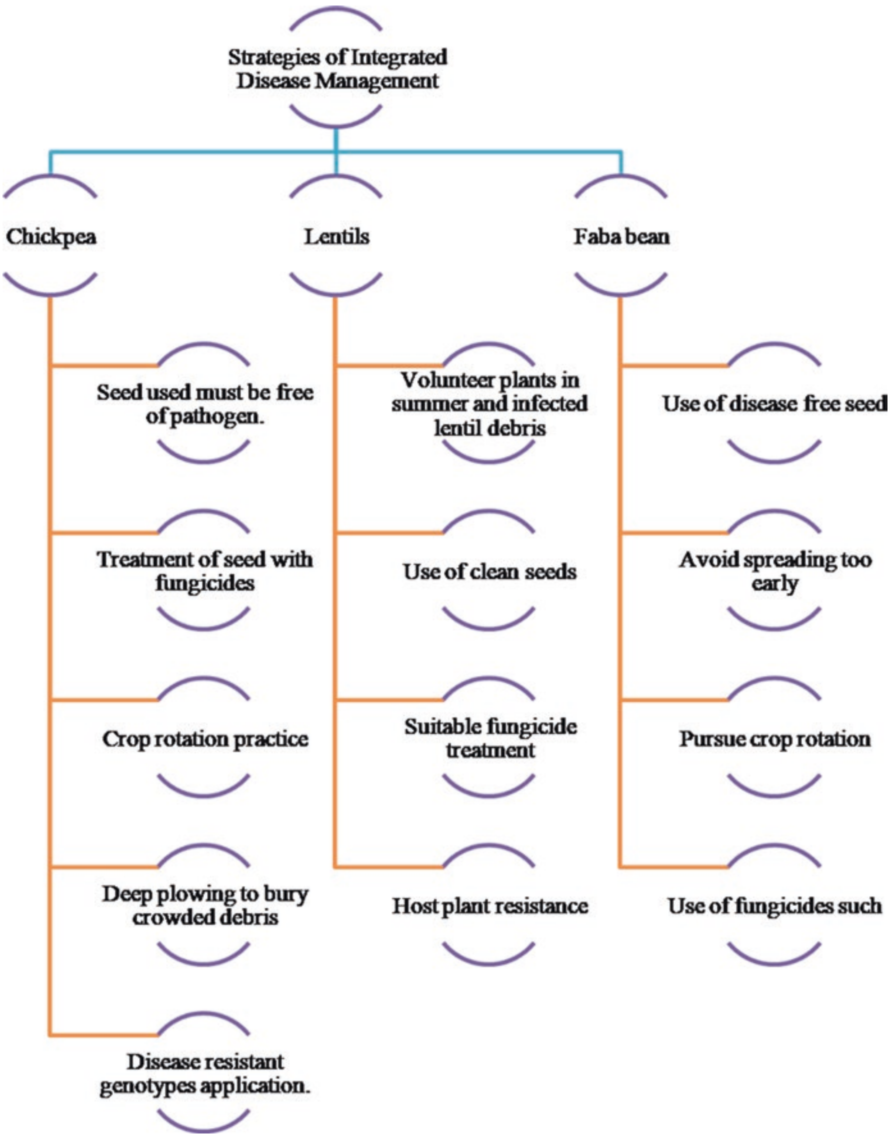

Fig. 3.2 Strategies of integrated disease management in chickpea, lentils, and faba bean

quality. Sustainable agriculture management is carried out for future generations in the form of farming (Folgarait 1998). Sustainable agriculture management comprises the following:

(a) Meet human needs
(b) Natural resources are protected
(c) Prevent degradation of water quality, etc.
(d) Nonrenewable resources efficiently used

(e) Natural organic cycles used
(f) Assure the economic survival of farmers
(g) Institutional incentives created for environmental stewardship

Along with sustainability, new technologies have also improved agricultural production. BMPs are used presently by targeting the applications rather than broadcasting. Cultural practices, biological pest control, new disease resistance hybrids, and many more ways are being implemented (Liang et al. 2016).

3.8 An Outlook for Sustainable Disease Management

Sustainable management of fungal diseases includes exploitation of host resistance, use of synthetic fungicides, and cultural and physical methods, which is discussed below.

The exploitation of host resistance: To control fungal diseases, host resistance is used as an efficient, inexpensive, and effective way. In this segment, available information is integrated for identification of resistance source; molecular markers combine with disease defiance gene identification and improved disease resistance genes (Toyoda et al. 2002). Mainly cultivars are used in host-plant resistance which can tolerate pathogen attack. The interaction between genetic factors in the pathogen and the plant determines the expression of plant resistance. Host-plant resistance could become a deficit when exposed to unsuitable environmental conditions (Andersen et al. 2018). As observed on phoma stem canker (*Leptosphaeria maculans*) of oilseed rape, disease resistance can be dependent on temperature (West et al. 2001) where resistance is expressed at 15 °C but not at 25 °C (Mitrousia et al. 2018).

Protection with fungicides: The usual approach for fungal disease management is the application of fungicides. Disease management in a traditional way is the use of immense spectrum of fungicides as seed treatment chemicals and foliar sprays. Numerous testing were focused on *Cercospora* leaf spot, anthracnose, and powdery mildew, and some trials were on *Macrophomina* blight, web blight, and dry root rot. DMI (demethylation inhibitors) and MBC (methyl benzimidazole carbamate) are the effective fungicides that control foliar diseases. Instantly, after the appearance of disease symptoms, foliar spray was applied followed by second and third sprays after15–20 days from the first spray for anthracnose, powdery mildew, and *Cercospora* leaf spot. Counter to wet and dry root rot seed treatment is applied. Carbendazim is an effective fungicide against dry and wet root rot disease (Rathore et al. 2008; Sumrra et al. 2015). As recommended by the Fungicide Resistance Action Committee (FRAC), various management strategies, markedly, rotation of treatments of a fungicide tank mix of broad spectrum and the fungicides that are selected and integrated fungicide spray program along with elements of disease controlling practices are executed at various levels of organizing bodies of many countries (Vincelli 2002). However, sometimes disease management failures are observed. For example, isolates of *C. kikuchii* (*Cercospora* leaf spot) from soybean fields in the USA were reported to be unaffected by thiophanate-methyl (Soares et al. 2015). Isolates of *Ascochyta* blight of chickpea also reported being unresponsive to chlorothalonil, fluxapyroxad, prothioconazole, and pyraclostrobin. Next-generation fungicides are therefore used which are the derivatives of natural products. These are ecologically safer and effective at reduced doses (Khani et al. 2016; Salam et al. 2011; Pande et al. 2005).

Cultural and physical practices: To terminate seed-borne pathogens, various cultural and physical methods are used to control *Cercospora* foliar blight. In foliar diseases, field cleanliness, crop rotation, etc. is important (Tagne et al. 2008). For example, mung bean seed analysis with gamma rays and storage of 90 days at a subduing effect on root rot fungi (Ikram and Dawar 2017). Computing diversity in the crop rotations maintains the sustainable management of soil-borne diseases. Crop rotation, plant residue management, etc., are productive for controlling diseases in climatic surroundings (Chakraborty 2013; Juroszek and Von Tiedemann 2015).

3.8.1 Challenges for Sustainable Management

Quite a lot of challenges prevail in the enactment of unified supervision, and a lack of suitable understanding of integrated pest management exists among the farmers. For example, gamma rays are used for seed treatment in eliminating the seed-borne pathogen, but in the case of smallholder farmers, it's ineffective because the production of seeds in their farm is done on a small scale. With several studies, disease resistance genotypes were assessed in limited localities or seasons. The pathogen population varies among dissimilar geography, and for that reason, screening of emerging breeding lines for disease resistance should be done in multiple locations (Rebaudo and Dangles 2013;) (Crowder and Harwood 2014).

Various attempts are implemented for the production and application of biopesticides in the undeveloped countries. Several biopesticides just conquer the disease and not effectual as chemical fungicides, and hence the growers are unwilling to use the products. The farmers in those countries are not well equipped with knowledge about the influence of global climate change in disease management which affect the improvement and durability of plant protection chemicals and biocontrol agents which can be a vital task to manage foliar imminent diseases (Afreh-Nuamah and Akotsen-Mensah 2015; Heong et al. 2013).

3.9 Conclusion

Legumes such as chickpea, lentil, faba bean, and cowpea are consumed by the major population worldwide. This chapter dealt with the diagnosis and epidemiology of the fungal foliar diseases such as *Ascochyta* blight, *Botrytis* gray mold, rust, chocolate leaf spot, and *Cercospora* leaf spot and how to control them. In this chapter, the development of the management of foliar diseases of both cold and warm season legumes has been explored. Previous researches were based on resistant sources and chemical control of scarce diseases, whereas the present IDM program lies in identifying, evaluating, merging, and locating distinct components. In spite of the various IDM modules developed to tackle diseases of legumes, but, a gap exists between farmers and scientists. Therefore, IDM technology might be expanded by increasing farmer awareness and the crop residue quality of food legumes which are the vital components of the mixed crop-livestock system.

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