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Integrated foliar diseases management of legumes

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ABSTRACT

Of the most important food legumes grown world over, chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik.), faba bean (*Vicia faba* L.), grasspea (*Lathyrus sativus* L.) and field pea (*Pisum sativum* L.) are grown in cool season, while pigeonpea (*Cajanus cajan* (L.) Millsp.), blackgram (*Vigna mungo* (L.) Hepper), mungbean (*V. radiata* (L.) Wilczek), horsegram (*Macrotyloma uniflorum* (Lam.) Verdc.), cowpea (*V. unguiculata* (L.) Walp) and soybean (*Glycine max* (L.) Merr) are known as warm season legumes. Biotic stresses such as diseases, insect-pests, nematodes and weeds substantially reduce the yield of these legumes in farmers' fields. Among these, fungi and viruses are the largest and most important groups affecting all parts of the plant at all stages of growth of both cool season and warm season food legumes. According to estimates made in India nearly 10-15% of food legumes production is lost due to diseases alone. Among fungi, diseases caused by species of *Botrytis* and *Ascochyta* are of great importance to faba bean, lentil, chickpea and field pea. The genus *Stemphylium* causes foliar disease in lentil and chickpea and *Septoria* species causes leaf spots in cowpea. The viruses of major economic importance on cool season legumes belong to the Luteoviruses, Nanoviruses, Potyviruses, Carlaviruses, Furoviruses. Perusal of the literature on diseases of food legumes and their management reveals new records of diseases, loss estimations, biology of causal agents, identification of host plant resistance and fungicide use. The purpose of this paper is to review the etiology and biology of major foliar diseases of food legumes and outline current and suggested future research on issues related to disease management strategies globally. Integrated disease management (IDM) modules for important foliar and viral diseases of chickpea (ascochyta blight and botrytis gray mold), pigeonpea (sterility mosaic and Phytophthora blight), lentil (rust, ascochyta blight and stemphylium blight), faba bean (ascochyta blight, chocolate leaf spot and rust), field pea (powdery mildew and Ascochyta complex), mungbean and urdbean (viral diseases and chocolate leaf spot) and cowpea (viral diseases and chocolate leaf spot) are discussed. The IDM involves the individual component of disease management such as host plant resistance (HPR), agronomic practices, judicious use of fungicides, pesticides for vector control, biopesticides for pathogen control, risk forecasting that operate on different aspects of the disease etiology, such that they complement each other and can be applied together in farmers' fields collectively to provide farmers with maximum economic return.

Introduction

Grain legumes play an important role in improving livelihood, nutritional security of farmers and populations in less developed countries as well as sustainability of agriculture in dry areas worldwide. Chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik.), faba bean (*Vicia faba* L.), grasspea (*Lathyrus sativus* L.) and field pea (*Pisum sativum* L.) are grown in cool season, while pigeonpea (*Cajanus cajan* (L.) Millsp.), blackgram (*Vigna mungo* (L.) Hepper), mungbean (*V. radiata* (L.) Wilczek), horsegram (*Macrotyloma uniflorum* (Lam.) Verdc.), cowpea (*V. unguiculata* (L.) Walp) and soybean (*Glycine max* (L.) Merr.) are the warm season legumes. Grain legumes (chickpea, lentil and pea) are important rotational crops in the Pacific Northwest and Northern Great Plains of the United States and central California. The introduction of pulse crops into the agricultural systems in Western Australia (WA) is relatively recent and has been supported by considerable research to adapt and develop varieties and production systems to suit this Mediterranean environment. These grain legumes grown worldwide are prone to attack by a large number of plant pathogens, from fungi, bacteria, phytoplasmas, and viruses to nematodes and parasitic angiosperms, which result in severe economic losses globally. Among these, fungi and viruses are the largest and perhaps the most important groups affecting all parts of the plant at all stages of growth (Table 1). Foliar diseases such as gray mold, chocolate spot, Ascochyta blight caused by species of *Botrytis* and *Ascochyta* are of

Table 1: Important foliar diseases of food legumes and their distribution

Food legume	Disease	Causal organism	Distribution	Losses
Cool season legumes				
Chickpea (*Cicer arietinum* L.)	Ascochyta blight	*Ascochyta rabiei*	West Asia, northern Africa, Mediterranean region	> 50%
	Botrytis gray mold	*Botrytis cinerea*	India, Nepal, Bangladesh, Pakistan, North Africa, Australia, America	50-100%
	Stunt	Bean leaf roll luteovirus (BLRV)	North Africa, Middle East, India, Spain, Turkey and the USA.	
Lentil (*Lens culinaris* Medik.)	Rust	*Uromyces viciae-fabae*	Bangladesh, Chile, Ecuador, Ethiopia, India, Morocco, Nepal and Pakistan	50-100%
	Ascochyta blight	*Ascochyta lentis*	Argentina, Australia, Brazil, Canada, Chile, Cyprus, Ethiopia, Greece, Iran, Jordan, New Zealand, Pakistan, Russia, Spain, Syria, and USA.	Up to 70%
	Stemphylium blight	*Stemphylium botryosum*	Bangladesh, Egypt, Syria, and USA	Up to 70%
Faba bean (*Viciae faba* L.)	Ascochyta blight	*Ascochyta fabae*	Mediterranean countries	5-50%
	Chocolate leaf spot	*Botrytis cinerea / Botrytis fabae*	Mediterranean countries	Up to 50%
	Rust	*Uromyces viciae-fabae*	Mediterranean countries	Up to 50%
	Necrotic yellows	Faba bean necrotic yellows virus	West Asia and North Africa	Up to 80%
Field pea (*Pisum sativum* L.)	Powdery mildew	*Erysiphe polygoni*	India, Nepal	10%
	Downy mildew	*Peronospora viciae*		30%
Warm season legumes				
Pigeonpea (*Cajanus cajan* [L.] Millsp.)	Sterility mosaic	Pigeonpea sterility mosaic virus	Bangladesh, India, Myanmar, Nepal, Sri Lanka and Thialand	Annual loss of 205, 000 tonnes in India (Kannaiyan *et al.* 1984)
Mungbean (*Vigna radiata* [L.] Wilczek and black gram (*Vigna mungo* [L.] Hepper)	Yellow vein mosaic	*Mungbean yellow mosaic virus*	Bangladesh, India	10-100%
	Cercospora leaf spot	*Cercospora cruenta, C. canescens*	Bangladesh, India, Indonesia, Taiwan, Thailand, Philippines, Malaysia	Upto 50%
	Powdery mildew	*Erysiphe polygoni*	India, southeast Asian countries	9-50%
Cowpea (*Vigna ungiculata* [L.] Walp.)	Cercospora leaf spot	*Cercospora canescens* and *Pseudocercospora cruenta*	Fiji, Brajil, Kenya, Nigeria, Zimbabwe, India, Bangladesh, Egypt, Iran, Japan, Malaysia, Thailand	18-42%
	Cowpea golden mosaic	Cowpea golden mosaic virus	Kenya, Nigeria, Tanzania, Cuba, Surinam, USA	60-100%
	Cowpea aphid-borne mosaic	Cowpea aphid-borne mosaic virus	Europe, Africa, Mediterranean basin, Turkey, Iran, India, Indonesia, China, Japan, Australia, Brazil, USA.	13 - 87%

great importance to faba bean, lentil, and chickpea. The genus *Stemphylium* causes foliar disease in lentil and *Septoria* species causes leaf spots in cowpea. Around 45 viruses are reported to infect legumes (Bos *et al.*, 1988; Makkouk *et al.*, 2003) worldwide. However, only few are of major economic concern with respect to specific regions. Among the more important groups are the Luteoviruses, Nanoviruses, Carlaviruses, Furoviruses and Potyviruses. The Potyviruses are the most important overall causing economically important diseases in grain legumes. Many of the viruses are seed borne in their legume hosts; some are sufficient to have enabled worldwide distribution.

There are reviews dealing with the individual foliar diseases of cool season and warm season legumes (Kaiser *et al.,* 2000; Pande *et al.*, 2007; Tikoo *et al.*, 2005). In this chapter, attempts have been made to address the management of major foliar diseases of both cool season (chickpea, lentil, faba bean, and field pea) and warm season [pigeonpea, mungbean (greengram), urdbean (blackgram) and cowpea] food legumes and outline current and suggested future research on issues related to importance and disease management strategies for these diseases globally. Integrated disease management strategies for economically important foliar diseases of chickpea (ascochyta blight, botrytis grey mold), pigeonpea (sterility mosaic and phytophthora blight), lentil (rust and stemphylium blight, ascochyta blight), faba beans (chocolate leaf spot), field pea (powdery mildew) and green gram and black gram (viral diseases) have been discussed in details with reference to the available research results on the biology of the pathogen and etiology of the disease to device successful disease management strategies. A successful integrated disease management (IDM) strategy is one under which grain legumes have been protected from the yield-reducing effects of the pathogen rendering the later to economic insignificance. The IDM involves a total system approach to the suppression of pathogen populations to a level where higher yields can be obtained and enables the farmers to achieve maximum economic return. In the IDM system, the individual component of disease management such as host plant resistance (HPR), agronomic practices, judicious use of fungicides, pesticides for vector control, biopesticides for pathogen control etc., need to be compatible or complimentary.

Management of foliar diseases of food legumes

The main emphasis in research and development to combat food legume diseases is on host resistance and chemical control where ever applicable, and quite often these components of disease management were practiced in isolation to each other. Recently a shift in scientific thinking and practice in the management of grain legume diseases has been seen and greater emphasis was on identifying, evaluating, and integrating location specific components of integrated disease management (IDM). In general IDM has followed the principles of IPM (Jeger, 2000). The location specific IDM of food legumes is primarily based on host plant resistance (HPR) or genetic resistance; additionally other components of diseases management. In some environments, IDM may require a single component used alone (usually HPR) or in combination with one other component (such as fungicide seed treatment) to adequately combat diseases of food legumes. The components of IDM employed in the production of food legumes are listed as follows:

Host plant resistance (HPR),

Disease modeling (prediction) for avoidance of high risk or disease pressure,

Chemical sprays (fungicides, pesticides),

Biological control, and

Cultural (agronomic) practices (sowing dates, plant population etc.).

In this review, disease management practices to control economically important foliar diseases of food legumes have been discussed (Table 2). Management of viral diseases has been discussed separately under the virus disease control section.

3. Cool season legumes

3.1 Chickpea (*Cicer arietinum* L.)

Major foliar diseases of potential economic importance in chickpea are ascochyta blight (AB) and botrytis grey mold (BGM). These diseases have been comprehensively reviewed by several workers in the past (Nene and Reddy, 1987; Nene *et al.,* 1991; Haware, 1998; Singh and Sharma, 1998; Pande *et al.*, 2005). Recently Pande *et al.* (2007) have discussed advances in etiology, biology and management of diseases of food legumes and Singh *et al.* (2007) have discussed chickpea diseases and their management in detail.

Ascochyta blight infection and disease progression occur from 5^0 to 25 ^{0}C with an optimum temperature of 16-20 ^{0}C, and a minimum of 6 h leaf wetness. Disease severity increases with the increase in relative humidity (Trapero-Casas and Kaiser, 1992). Cloudiness and prolonged wet weather favour rapid development and spread of both the diseases. The pathogen survives on infected or contaminated seeds, infected chickpea debris which causes AB, produces both rain splashed conidia and wind blown ascospores. The existence of 2-12 races of *A. rabiei* has been proposed by several researchers (Chongo *et al.,* 2004; Phan *et al.,* 2003). Basandrai *et al.* (2005) grouped 14 isolates of *A. rabiei* into eight pathotypes at >0.5 similarity coefficient.

Infection of BGM occurs from 15-25 ^{0}C with an optimum temperature of 20-25 ^{0}C. High moisture and high relative humidity are congenial for BGM development. Under such conditions there is abundant sporulation of the fungus *B. cinerea* on dead plant parts, particularly on flowers and pods (Pande *et al.*, 2006). The pathogen *B. cinerea* is reported to have extreme diversity and adaptability to a wide range of environmental conditions. Existence of 4 - 5 pathotypes of *B. cinerea* has been reported from northern India (Rewal and Grewal, 1989; Pande *et al.,* 2006).

Adoption of IDM practices is essential for economical and effective control of AB and BGM. In several studies conducted in different chickpea growing areas of the world, several sources of resistance to AB were identified (Pande *et al.* 2005). Furthermore, development of AB resistant genotypes has made it possible to sow the crop during winter in the Mediterranean region thereby doubling the chickpea production potential. On the other hand, an adequate level of genetic resistance to BGM is not available in the cultivated genotypes and fungicides become ineffective under the high disease pressure. Hence, IDM using the available management options is essential to successfully manage the disease and mitigate yield losses. Moderate level of HPR can be combined with other cultural practices and/or application of minimum dosage of fungicides for control of AB and BGM.

A combination of a moderately resistant variety and 2 sprays of chlorothalonil, one during the seedling stage and another at the early podding stage, provided the most economical field control of AB in Syria and Australia (Reddy and Singh 1990, Bretag *et al*. 2008). In collaboration with the Syrian national program, ICARDA has developed an IDM package for AB management (Akem *et al*., 2000). The components of this package include use of tolerant cultivars adapted to early sowing, seed dressing with fungicides, and single foliar application of chlorothalonil at seedling or early vegetative growth stages. This package resulted in higher chickpea yields compared with the traditional spring plantings using a local variety without seed dressing or fungicide spray (ICARDA 2003).

Agronomic and cultural management of BGM has been demonstrated in India, Bangladesh and Nepal (Pande *et al*., 2002). In Bangladesh, an IDM package, comprising cultivation of the BGM tolerant genotype "Avarodhi", soil application of diammonium phosphate, wider row spacing , seed treatment with carbendazim + thiram (2g/kg seed), and need based foliar application of carbendazim, has been devised (Bakr et al., 2005; Pande et al., 2005, 2006).

The location-specific recommended IDM practices for AB include: (*a*) use of pathogen-free seed, (*b*) seed treatment with fungicides, (*c*) practice of crop rotation, (*d*) deep ploughing of chickpea fields to bury infested debris, (*e*) use of disease-resistant genotypes, and (*f*) strategic application of foliar fungicides.

3.2 Lentil (*Lens culinaris* Medik.)

Ascochyta blight, rust and powdery mildew are economically important foliar diseases of lentil. Ascochyta blight is caused by *A. lentis* produces conidia, in a flask-shaped fruiting body (pycnidium), which are spread by rain splash. The teleomorph, *Didymella lentis*, produces ascospores which can be wind dispersed large distances. The pathogen is both stubble and seed borne. Progress of foliar blight is rapid and epidemic levels can be reached under cool and wet weather conditions as a consequent of spores being disseminated by rain splashes. It survives for more than 3 years in infected pods and seeds at 4-5 ^{0}C or under shelter outdoors, and 1-5 years at the soil surface. IDM of Ascochyta blight of lentil includes use of resistant cultivars, use of disease free seed, crop rotation, seed treatment and foliar spray. Application of the fungicides benomyl, carbendazim, thiabendazole, chlorothalonil, prothioconazole and strobilurin, are useful for managing Ascochyta blight epidemics.

Lentil rust is caused by *Uromyces vicia- fabae* (Pers.) de Bary. It is an autoecious fungus; completing its life cycle on lentil. The disease occurs during the flowering/early podding stage as aecia, which may develop into secondary aecia or uredia. The resulting aeciospores and uredospores lead to a further disease spread in the crop season. Uredia rapidly appear a little late in the crop season followed by development of telia. The fungus survives in summer as teliospores. High humidity and cloudy weather with temperatures of 20-22 ^{0}C favor disease development. The plants give dark brown or blackish appearance visible as patches in the field.

Integrated management of rust includes control of volunteer plants over the summer and removal of infected lentil debris. It is advisable to use clean seeds without rust contaminations, and to treat the seed with a suitable fungicide such as diclobutrazole. Preventive fungicide sprays of mancozeb at early disease development stage have been recommended. The use of host plant resistance is the best means of rust management. Several rust resistant cultivars have been released in different countries, with resistance originally identified at ICARDA, Syria and in India (Basandrai *et al.*, 2000, Tikoo *et al.*, 2005). There is no clear evidence for the existence of races. Both complete and partial resistance exists and monogenic resistance has been reported (Sinha and Yadav, 1989). Field resistance of lentil to rust is governed either by a single dominant gene, by two independently inherited dominant genes, by two complementary genes or by three independently inherited genes (Basandrai *et al.*, 2005).

Powdery mildew another important disease of lentil has been reported from many countries such as Cyprus, Ethiopia, India, Siberia, Sudan, Syria, Tanzania and the former USSR. In North America, powdery mildew is often observed after lentil started flowering. The disease poses a serious problem on breeding material in plastic or glass houses in both India and Syria, and in India it is also recorded in off-season nurseries in Trans Himalayan regions, like Lahaul Spiti and Sangla etc., but it is rarely seen in the field during the cropping season. A fine powdery, white growth of conidia and mycelium initiates as small spots and rapidly spreads to cover the entire surface of leaves, stems and pods. Later, the leaflets become dry and curled, and are shed prematurely, causing considerable reduction in yield and seed quality. The seeds from infected plants remain small and shrivelled.

Powdery mildew of lentil is caused by the ectoparasites *Erysiphe pisi DC., and E. polygoni* DC. and the endoparasite *Leveillula taurica* (Lév.) Arnaud. Recent evidence showed that *E. trifolii* also infects lentil (Attanayake *et al.*, 2008). The anamorph stage is responsible for spread of the disease. The teleomorph stage has been reported to occur in India and Sudan (Chitale *et al.*, 1971). Moderately high temperatures and moderate relative humidity favour the disease development. Many lentil genotypes are reported resistant to powdery mildew (Tikoo *et al.*, 2005), and should be planted whenever possible. Foliar sprays with fungicides benomyl, tridemorph, aqueous sulfur, karathane (dinocap), calixin or sulfex (ferrous bisulfide) as well as certain insecticides (Quinalphos, Tnazophos, Phoxim) applied at 10-15 days interval are effective in suppressing mildew growth (Beniwal *et al.*, 1993).

3.3 Faba bean (*Vicia faba* L.)

Ascochyta blight, chocolate leaf spot and rust are the major diseases of faba bean (van Emden *et al.,* 1988). Ascochyta blight also known as leaf, stem, and pod spot is caused by *Ascochyta fabae* (teleomorph *Didymella fabae* Jellis & Punnith). Both stages are described by Jellis and Punithalingam (1991). The fungus is highly specialized to faba bean and is highly variable in culture. Rashid *et al.* (1991) identified seven genes of resistance and resistance was either monogenic or oligogenic. Limited information is available about the biology of *A. fabae* (Jellis *et al.,* 1998). More work needs to be done to standardize methods and differential cultivars to establish the *A. fabae* races.

Chocolate leaf spot is caused by both *Botrytis cinerea* Pers. ex Pers. and *Botrytis fabae* Sard. A teleomorph of *B. fabae*, *Botryotinia fabae*, was described by Wu and Lu (1991). *B. cinerea* is a parasite and saprophyte on a wide range of host plants, whereas *B.* fabae is specialized for the invasion and colonization of *Vicia* spp. especially *V. faba*. The existence of races of *B. faba* has been proposed on the basis of reaction to differentials in Mediterranean countries. More work needs to be done to understand variability in *B. fabae*. Etiology and biology of the fungus is discussed in detail by Jellis *et al.* (1998).

Another disease of faba bean, brown rust is caused by the fungus *Uromyces viciae fabae* (Pra.) Schroter. The pathogen predominantly produces aeciospores and uredospores on leaves, and teliospores are formed in large black sori on stems and petioles (Jellis *et al.,* 1998). While earlier studies mostly focused on cytological aspects, later studies were concerned with biochemical and molecular characteristics. Despite the fact that there is still no stable transformation system available for any obligate biotroph, recent molecular analyses have provided new insights into this highly sophisticated interaction of a fungus with its host (Ralf T Voegele, 2006).

IDM strategy for controlling foliar diseases of faba bean includes the use of disease free seed, avoid sowing too early to minimise disease, follow 3 - 4 year crop rotation and select the tolerant variety to the main disease risk in particular region. Thorough and regular crop monitoring is essential if the strategic spray program is to be successful. The timing of fungicide applications depends on the disease level observed, the time since the previous application, and the likelihood of rainfall and other conditions conducive to infection and spread of chocolate spot. Carbendazim is best used when high chocolate spot pressure occurs or when rapid plant growth produces large amounts of unprotected foliage, particularly from mid-flowering onwards. Cholorothalonil and mancozeb are best to be used earlier if rust or Ascochyta is a problem.

3.4 Field pea (*Pisum sativum* L.)

Peas are adversely affected by serious fungal, bacterial and viral diseases such as: powdery mildew *(Erysiphe pisi Syd. (syn. E. polygoni* DC), Ascochyta blight or black spot (*Ascochyta pisi/A. pinodes*), downy mildew *(Peronospora pisi),* bacterial blight *(Pseudomonas pisi)*, *Pea early browning virus* (PEBV), *Pea enation mosaic virus* (PEMV) and Pea mosaic virus (PMV) (Davies *et al.,* 1985; Muehlbauer *et al.,* 1995; van Emden *et al.,* 1988). Kraft *et al.* (1998) has comprehensively described pea diseases. Etiology and biology of these diseases is reviewed in detail by Saxena and Khare (1998) and Baaya and Erskine (1998).

Powdery mildew occurs all over the world and can cause severe damage in areas where pea is cultivated (Kraft and Pfleger, 2001). Powdery mildew of pea caused by *Erysiphe pisi*, is a serious disease both in the field and in the greenhouse. All aboveground parts of plants are susceptible to powdery mildew. Pod infection may discolor seeds to a gray brown color. The powdery look of the disease is caused by the profuse production of conidia on the upper leaf surface. Management of powdery mildews of grain legumes is through use of resistant cultivars, especially in late sown crops, which are likely to experience high disease pressure. Resistance in pea is conditioned by two recessive genes (*er-1* and *er-2*) along with two or more modifying genes. Resistance in cultivars homozygous for *er-2* is expressed mostly in leaves and this resistance can be rendered ineffective under high disease pressure. The disease is often less severe in areas where overhead irrigation is applied regularly because long periods of free water on host leaves reduce conidium viability and wash conidia from host tissue. Other control measures include fungicide sprays of sulfur and/or demethylation inhibitors such as cyproconazole, fenarimol and triadimenol. Fungicide spray should be applied at least two weeks before harvest to avoid residue on peas.

Ascochyta blight or black spot is the most common and most damaging disease of field pea in southern Australia. Worldwide, the disease is recognized as being caused by any one, or combinations, of three fungi; *Mycosphaerella pinodes, Phoma medicaginis* var. *pinodella* and *Ascochyta pisi*. All three frequently occur together hence the disease is generally referred to as the ascochyta complex of peas. *Mycosphaerella pinodes* causes the most damage to pea crops in Western Australia, Washington, USA and is the principal pathogen involved in nearly all occurrences of blackspot. *Mycosphaerella pinodes* survives on pea stubble for more than 3 years producing viable ascospores during each growing season. Ascospores are released from pseudothecia on the stubble following rain events of as little as 0.2 mm. The airborne ascospores can infect crops several kilometres away.

IDM includes use of moderately resistant varieties, disease free seed, crop rotation, delay in the sowing, disease forecast model that predicts the time of onset, and progression of ascospores maturity and spread of spores from the source of infection and need based foliar and in-furrow applications of fungicides in conjunction with other agronomic practices (Kraft *et al.*, 1998).

4. Warm season legumes

4.1 Pigeonpea (*Cajanus cajan* (L.) Millsp.

Sterility mosaic disease (SMD) is the most important foliar disease of pigeonpea in India and Nepal (Reddy and Vishwa Dhar, 2000). Etiology of sterility mosaic is unknown despite of numerous attempts during the past 20 years. Lava Kumar *et al.* (2000) reported a tenui virus of asymmetric morphology as the cause of SM disease and retained the name of virus as Pigeonpea sterility mosaic virus (PPSMV). PPSMV is flexous, branched filaments measuring 3-8nm in diameter. The SM causal agent is not transmitted through sap or seed. It is transmitted by the eriophyid mite vector. Biology of the mite vector is discussed in detail by Reddy *et al.,* (1990). Information on physiological specialization of SM is limited and is based on symptoms observed on the inoculated plants using the mite vector (Reddy *et al.,* 1990). Recently PCR based techniques are being developed for distinction of different species of eriophyid mites (Vishwa Dhar *et al.,* 2005).

HPR is the most reliable and sustainable method for the management of SMD. Considerable progress has been made in identifying resistance sources and developing resistant cultivars to the disease. Some attention has also been paid to cultural and chemical control of sterility mosaic. Cultural practices include: Destroy ratooned pigeonpea, uproot and destroy infected plants at the initial stage of disease development, crop rotation to reduce inoculum levels and vector populations, chemical control as seed treatment with 25% carbofuran or 10% aldicarb (3g kg^{-1} seed) and spraying acaricides or insecticides like karathane, metasystox to control the mite vector in the early stages of plant growth (Reddy *et al*, 1990).

4.2 Mungbean (*Vigna radiata* (L.) Wilczek) and blackgram (*Vigna mungo* (L.) Hepper

Mungbean (green gram) and urdbean (black gram) are widely cultivated in many Asian countries in different seasons. Three diseases (yellow mosaic, Cercospora leaf spot and powdery mildew) that attack both the pulses are considered economically important. Yellow mosaic caused by mungbean yellow mosaic virus (MYMV) is the most serious limiting factor in mungbean and urdbean cultivation. The pathogen is transmitted by the white fly *Bemisia tabaci* Genn. Transmission of the virus is discussed in detail by Singh *et al.* (1998). Cultivation of resistant varieties, manipulation in sowing dates, inter/ mixed cropping of mungbean and urdbean with non-host crops like sorghum, pearl millet and maize and application of systemic insecticides such as aldicarb, disyston and foliar application of metasystox has been found effective in controlling the disease by reducing vector control (Vishwa Dhar *et al.*, 2004).

Cercospora leaf spot caused by *Cercospora cruenta and C. canescens* causes severe leaf spotting and defoliation at the time of flowering and pod formation. Involvement of different species in causing cercospora leaf spot complicates characterization of species. Singh *et al.* (2000) reported yield losses to the tune of 50% in severely diseased field. Since there is low level of resistance to cercospora leaf spot, the cultural practices and chemical control play an important role in its management. Cultural practices such as field sanitation, crop rotation, destruction of infected crop debris, and avoiding collateral hosts in the vicinity of the crop may help in reducing the incidence. Mancozeb, carbendazim, copper oxychloride and benomyl are reported to reduce disease incidence considerably (Singh *et al.*, 2001).

Powdery mildew caused by *Erysiphe polygoni* DC, is a problem in cool dry weather. Pathogen is obligate parasite and has wide host range. Limited information is available on the etiology and biology of *E. polygoni* on *Vigna mungo* and *Vigna radiata.* Available information on etiology and biology of the fungus is described in detail by Singh *et al.* (1998). Many resistant sources are available against powdery mildew (Vishwa Dhar *et al.*, 2004). Also its incidence can be reduced by adjusting the date of sowing with wider spacing. Chemical control with fungicides karathane, calixin, bavistin, benlate, topsin M, sulfur dust etc. has been found effective to control the disease under field conditions.

4.3 Cowpea (*Vigna ungiculata* (L.) Walp.)

Cowpea is the most important legume vegetable grown in India and to a limited extent in Nepal (Pande and Joshi, 1995) and Bangladesh (BARI, 1991). Cercospora leaf spot, cowpea golden mosaic and cowpea aphid-borne mosaic are of potential economic importance. Limited information is available about the distribution, etiology and biology of these diseases (Allen *et al.,* 1998; Saxena *et al.*, 1998). Cercospora leaf spot caused by *Cercospora canescens* and *Pseudocercospora cruenta* have been observed in all the cowpea growing areas. Despite the fact that cercospora leaf spot develops late in the season, disease spread is often rapid and premature defoliation can be severe. The disease can be controlled by combining resistant varieties and spray of fungicides such as benomyl and captafol post flowering.

Among viral diseases, *Cowpea golden mosaic virus* (CPGMV) and *Cowpea aphid-borne mosaic* (CABMV) are the two most important diseases of cowpea. CPGMV belongs to genus of *Begomovirus* and is transmitted by whiteflies (*Bemicia* sp.) and it produces intense yellow leaves which after sometime become distorted and blistered. CABMV is a

Table 2. Progress in integrated disease management (IDM) of foliar diseases in legumes

Crop	Disease	Components of IDM				References
		HPR	AP	CC	BC	
Chickpea	Ascochyta blight	**	*	*	*	Vishwa Dhar *et al.*, 2004; Pande *et al.*, 2005, Bretag et al, 2008
	Botrytis gray mold	**	*	**	*	Davidson *et al.*, 2004; Vishwa Dhar *et al.*, 2004; Pande *et al.*, 1998, 2006
Pigeonpea	Sterility mosaic disease	***	*	*	X	Vishwa Dhar *et al.*, 2004; Kumar *et al.*, 2006
Lentil	Stemphylium blight	**	*	**	X	Huq and Khan, 2007 Taylor *et al.*, 2007
	Ascochyta blight	***	*	**	X	Baaya and Erskine, 2004
	Rust	***	*	**	X	Taylor *et al.*, 2007
Field pea	Powdery mildew	***	*	***	*	Bretag *et al.*, 1995; Grunwald *et al.*, 2007
	Downey mildew	***	*	***	X	Grunwald *et al.*, 2007
	Rust	***	*	**	X	Grunwald *et al.*, 2007
Faba bean	Ascochyta blight	***	*	**	X	Jellis *et al.*, 1998
	Chocolate leaf spot	***	*	**	X	Jellis *et al.*, 1998
Mungbean and black gram	Yellow vein mosaic	***	X	***	X	Singh et al, 2002; Makkouk *et al.*, 2003
	Cercospora leaf spot	*	***	*	**	Singh et al, 2001
	Powdery mildew	**	*	**	X	Vishwa Dhar *et al.*, 2004
Cowpea	Cercospora leaf spot	***	*	**	X	Saxena *et al.*, 1998; Allen *et al.*, 2004
	Cowpea golden mosaic	***	**	*	X	Saxena *et al.*, 1998; Allen *et al.*, 2004
	Cowpea aphid-borne mosaic	***	**	*	X	Saxena *et al.*, 1998; Allen *et al.*, 2004

HPR=Host plant resistance, AP=Agronomic practices, CC= Chemical control, BC= Biological control

*, **, ***=low, medium and high potential, respectively; X = Not in common use

cosmopolitan, economically significant seed-borne virus of cowpea (Bashir *et al.,* 2002). The virus-infected seed provides the initial inoculum and aphids are responsible for the secondary spread of the disease under field conditions. The virus symptoms vary with the cowpea genotype and virus strain. Excellent sources of resistance are available for the breeding of resistant cultivars. Either a dominant or a recessive gene confers resistance in cowpea. Enzyme-linked immunosorbent assay (ELISA) is the most appropriate method for the detection of the virus in the seed or plant tissue for seed certification programmes.

5. Management of viral diseases of legumes

The development of an effective management package for virus diseases is dependent on the availability of basic information required to design an appropriate combination of interventions which can slow down virus disease development. The most important of these are: (i) identity of the causal agent, (ii) mode of transmission, (iii) ecology of the virus disease including that of its vector, (iv) extent and value of crop losses, (v) availability of genetic resistance, and (vi) available crop-protection methodologies and their applicability to specific farming systems and socio-economic situations. In many locations, however, such complete basic information is not yet available.

Control is optimized through IDM approaches, which combine all possible measures that operate in different ways such that they complement each other and applicable in farmers' fields. Thus, control measures can be classified as (i) those that control the virus, (ii) those that are directed towards avoidance of vectors or reducing their incidence, and (iii) those that integrate more than one method. Cultural practices such as healthy seed, rouging, alteration in sowing dates and use of early maturing cultivars are effective in minimizing virus disease incidence. Almost 50% of viruses affecting leguminous crops are seed-borne (Bos *et al.*, 1988). Seed-borne infections permit the introduction of primary virus inoculum into the field which facilitates secondary spread to reach a serious level in locations where the environmental conditions permit high vector activity. A close relationship between sowing date and the extent of subsequent virus spread is well documented for many crops. In Egypt and Syria, faba bean crops planted early are often severely attacked by *Faba bean necrotic yellows virus* (FBNYV), leading to complete crop failure (Makkouk *et al.,* 1998).

Host resistance is the most acceptable component in virus control because it is environment-friendly, practical and economically acceptable to farmers. There are many crop cultivars with adequate levels of virus resistance; in lentil against *Pea seed-borne mosaic virus* (PSbMV), *Bean yellow mosaic virus* (BYMV), *Alfalfa mosaic virus* (AMV), *Cucumber mosaic virus* (CMV), *Pea enation mosaic virus* (PEMV), *Bean leafroll virus* (BLRV), FBNYV and *Soybean dwarf virus* (SbDV), in chickpea against CMV, BYMV and PSbMV, in faba bean against BYMV, CMV, AMV, BLRV and PEMV, and in pea against BYMV, PEMV, PSbMV and BLRV. Another area of host resistance which is not well exploited is resistance to vector(s). Success in reducing virus spread by chemical control of vectors is likely with persistently rather than with non-persistently transmitted viruses

Each of the control measures mentioned provides only partial control, but combining genetic resistance, cultural practices, and chemical sprays is expected to lead to improvements. The use of host resistance, and one or two well-timed sprays coupled with optimal planting date and early roguing of virus-infected plants could offer reasonable and economic control and stabilize faba bean production. Each strategy needs to be affordable by farmers and fulfill the requirements of being environmentally and socially responsible. It must also be compatible with control measures already in use against other pests and pathogens.

6. Conclusions and future thrust

In this review, developments on management of important foliar diseases of both cool and warm season legumes have been discussed. Earlier research was mainly focused on resistant sources and chemical control of few diseases. Now the major emphasis is on identifying, evaluating and integrating location specific components of IDM. IDM packages of food legumes have been successfully refined and validated in partnership with stakeholders and end users.

Despite the development of various IDM modules to tackle economically important diseases of food legumes, gap persists between scientists and farmers, particularly in the developing countries. This is due to dynamic agro-eco systems and socio-economic conditions, and due to dynamic nature of host-pathogen interactions/co-evolution that necessitates refinement of IDM strategies. Therefore persistent need exists for refinement, validation, transfer and adoption of IDM modules. This underpins IDM strategy to manage diseases of food legumes. Our future activities will be focused on the expansion of IDM technology by increasing the awareness of farmers, and also on the importance of quality of crop residues of food legumes used as an essential component of the prevailing mixed crop livestock system in the West Asia and North Africa (WANA), Asia and Africa. In addition, IDM strategies will be developed/refined for emerging pathogens such as Phytophthora blight in pigeonpea and new pathotypes of ascochyta blight of chickpea. Experience over the last few decades has shown that plant viruses cannot be controlled by preventive measures only. The complicated ecology of many of the viruses which affect legume crops, and for this matter crops in general, calls for a strategy which is long term, sustainable, economically acceptable to the resource-poor farmers, and friendly to the environment. The most sound approach is to exploit all available measures and use them in an integrated fashion. Effective virus-disease control has always been and will continue to be by integrated management, that is by crop management or ecosystem management.

Additionally transfers of IDM Technology to NARS and Farmers and capacity building became the significant components of IDM research and development and have been very well encapsulated in the vision, mission, goal and strategy of international institutes (ICRISAT, ICARDA and IITA) working on food legumes. Also IDM has mobilized partners for poverty alleviation, food and nutritional security, and environment protection particularly in developing nations in Asia and Africa. Sharing of HPR with NARS for the management of foliar diseases of chickpea and sterility mosaic diseases of pigeonpea were few examples of successful transfer of IDM technologies.

Future IDM strategies will also account effects of climate variability-on pathogen dynamics that is contributing to emergence and resurgence of new strains/pathogens, necessitating the appropriate refinement for disease control. HPR, fungicides, natural plant products, biofungicides, botanicals and agronomic practices will remain the potentially viable options for IDM. In addition, the future modules will incorporate the latest advancements being made in the identification of biocontrol agents and products from biotechnological approaches such as marker-assisted selection, genetic engineering, and wide hybridization to develop cultivars with resistance to diseases (Ascochyta blight and Botrytis grey mould in chickpea). Emphasis will be on using information technology for disease modeling, developing decision support systems, and utilization of remote sensing to refine up-scale and disseminate IDM technologies.

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