Agriculture, Forestry and Fisheries
2023; 12(5): 134-144
http://www.sciencepublishinggroup.com/j/aff
doi: 10.11648/j.aff.20231205.11
ISSN: 2328-563X (Print); ISSN: 2328-5648 (Online)

Review Article

Field Pea (*Pisum sativum*) Diseases of Major Importance and Their Management in Ethiopia, a Review

Zenebe Wubshet Hordofa*, Zelalem Tamiru

Ethiopian Institute of Agricultural Research, Phytopathology and Natural Resource Research Departments, Jimma, Ethiopia

Email address:
tzenebe2006@gmail.com (Zenebe Wubshet Hordofa)
*Corresponding author

To cite this article:
Zenebe Wubshet Hordofa, Zelalem Tamiru. Field Pea (*Pisum sativum*) Diseases of Major Importance and Their Management in Ethiopia, a Review. *Agriculture, Forestry and Fisheries*. Vol. 12, No. 5, 2023, pp. 134-144. doi: 10.11648/j.aff.20231205.11

Received: August 28, 2023; **Accepted**: September 15, 2023; **Published**: September 27, 2023

Abstract: The field pea (*Pisum sativum*), is a significant legume crop that enhances soil fertility while providing curtail human nourishment. However, due to biotic factors like diseases, its productivity is quite low (1.67 t/ha). Hence, the objective of this study is to provide insight into the economic significance, distribution, and current management strategies for these most significant diseases as well as to establish future approaches. The current significant diseases affecting field pea production include fungal diseases such Ascochyta blight (*Ascochyta pisi*), powdery (*Erysiphe pisi*), and downy mildews, Fusarium wilt, and rust. The most severe of these are Aschochyta blight and powdery mildew, which on field pea in larger areas result in significance yield losses (30-75% and 50-86%, respectively), and under favorable environmental conditions, 100% losses can be expected. The majority of small-scale farmers in impoverished nations like Ethiopia, where these pests cause serious losses, cannot afford the chemical pesticides that are the mainstay of existing pest control tactics. Therefore, research on host pant resistance for these pests' management techniques and farmers to better understand frequent symptoms, whether on the field or in storage conditions, must be major areas of focus for reducing impact in the future.

Keywords: Ascochyta Blight, Powdery Mildew, Disease Complex, Field Pea, Management

1. Introduction

In the highland regions, field pea (*Pisum sativum*), a cool-season legume crop that is a member of the faba bean family, comes in third behind faba bean and common bean in terms of production [9]. Its relevance stems not only from its high protein content but also from the fact that it increases crop yield, which raises soil fertility (by its capacity to fix nitrogen). Due to its high nutritional value, the crop is used in underdeveloped nations as a "hunger break crop" and used as shirowet, which is eaten with local teff bread called injera. It is also used as livestock feed and is referred to as "poor man's meal [32, 49].

The centers of origin for Field pea are thought to be the highland of Ethiopia, Mediterranean, and Central Asia [71]. According to the study of USDA, the top producing nations for field peas are Canada, the Russian Federation, India, France, and Australia [68]. Today, it is grown across the temperate world, as well as in the tropical highlands of central and Eastern Africa (particularly Ethiopia), Southern Africa, and even some regions of Rwanda and Uganda [28, 32]. In addition, Ethiopia is regarded as the second most important source of field pea genetic diversity [13]. It was grown on 215,331 acres with a yield of 275,583 tons during the 2020/21 growing season [9].

Field pea predictions are quite low (approximately 1.67t/ha), primarily because of biotic factors present in different areas. These are listed as the current risks to field pea production in various regions of Ethiopia [65, 9, 59, 32]. These include Ascochyta blight, Fusarium wilt, powdery mildew, rust, and downy mildew. In addition, little host resistance and a lack of affordable fungicides make managing diseases like Ascochyta blight still very challenging. As a result, the objective of this review is to insight on the significance, geographic distribution, control measures, and their potential in the future developments of these field pea diseases in Ethiopia.

2. Status of Production and Main Restrictions

The main field pea-producing countries are Canada, Russia, China, India, and France. Among these, Ethiopia is the first and the sixth-largest producer in Africa and the world, respectively [64]. In the country, field pea ranks in second place, following faba bean from legumes, in production and area coverage (Figure 1). It covers 219,928ha with 275,583 quintal/annum in the country [18].

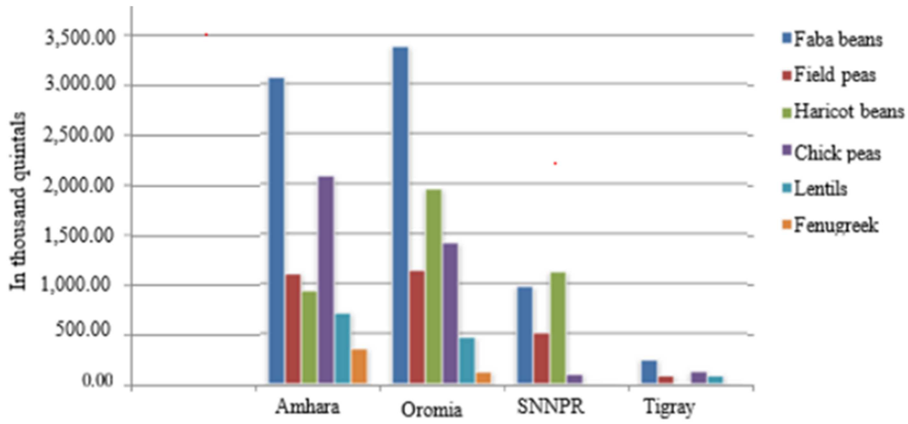

Figure 1. *Field pea production status in of Ethiopia.*

The regional and federal research centers have worked a lot on developing improved field pea varieties (Table 1) that offer better pest resistance, tolerance, and yields for the users [9].

Table 1. *Improved field pea varieties released across the country.*

Variety name	Variety name	Variety name	Variety name
FP DZ	Sefinesh	NC 95	Gedo –I
Mohanderfer	Holeta 90	Holeta	Tashale
G22 763-2C	Brkitu	Kaik	Harana
Gume	Bursa	Hursa	Weyib
Tegegnech	Agrit	Tulu-dimtu	Hortu
Wolmera	Lettu	Arji –I	Yewaginshe
Hassabie	Weyitu	Bariso	Jiidhaa
Adi	Dadimos	Bamo	Jeldu
Markos	Tullushenen	Ambericho	Lammiif
Megeri	Urji	Meti	
Adet –I	Milkiy	Senk	

Source: Ertiro and Haile [24]

Eventhough these varieties were developed and made available for various agroecologies, field pea production in Ethiopia is still hampered by various ailments. Numerous diseases pose a substantial danger to field pea production and result in significant yield losses. Additionally, the USA (63%), England and Australia (45%), Canada (39%), and Ethiopia (>50%) have reported on their effects [9]. Some of the documented diseases influencing its productivity include ascochyta blight, bacterial blight, root rot, damping off, downy and powdery mildew, Fusarium wilt, and different viruses [25, 37].

2.1. Ascochyta Blight

It is the current threat that is devastating field pea production across the country. A 26% yield reduction has been reported due to this disease [9]. The three spp. (*Ascochyta pisi*, *Phoma medicaginis* var. pinodella (*A. pinodella*), and *Mycosphaerella pinodes* (*A. pinodes*)) cause Ascochyta blight disease. They can happen independently in one pea field, even on a single plant (Table 2). *Mycosphaerella pinodes* is the main disease causing pathogen on field pea in Ethiopia [46, 65].

2.1.1. Pathogen Epidemiology and Host Ranges

Ascochyta blight pathogens can infect all the above-ground parts (the foliar) and overwinter in the seed, infected crop residue, and soil. Infected seeds can also serve as the primary sources of inoculum for new crops, with up to 86% transmission efficiency. This means that when infections originate from the seed, young plants can be invaded directly by the pathogen that existed as Sclerotia (thickened mycelia) of *D. pinodes*. It can also survive as chlamydospores, mycelium, Sclerotia, or Pycinida on straw fragments and its conidia adhere to the seed surface [21, 41, 12].

A. pinodes underwent both sexual (production of pseudothecia that discharges ascospores) and asexual (formation of pycinida, which convey conidia) forms. Also, the pathogens (*D. pinodes* and *P. medicaginis*) produce chlamydospores that are able to survive in the soil for a minimum of 5 years, whereas the period of ascospores formation is a minimum of six days for pycinida and 13–14 days for pseudothecia, which allow multiple generations of fruiting bodies [56a, 12, 42]. In spite of the types of inoculum, initial infection results in small purple to black spots that expand when they get moist [3]. Under low temperature and moderate moisture conditions, old pycinida mature, new pycinida and, perithecia develop, and their spores are released (Figure 2).

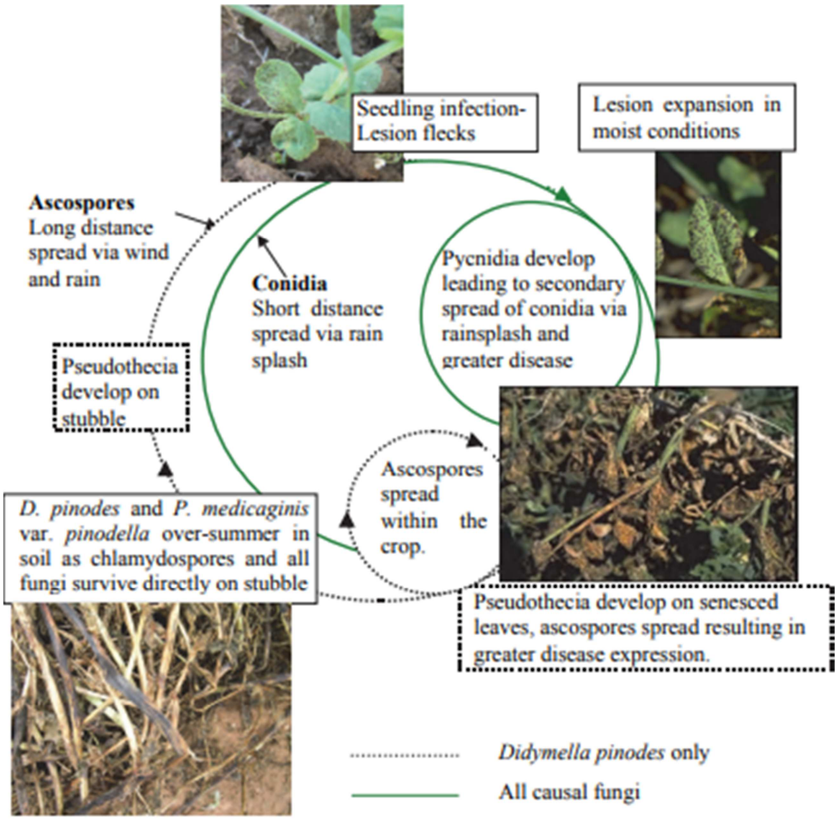

Figure 2. *Ascochyta blight diseases cycle [20].*

Ascochyta blight has wide host ranges and can infect more than 20 plant genera in more than 50 plant species. This includes soybean (*Glycine max*), field pea (*Pisum sativum*), lentil (*Lens culinaris*), alfalfa (*Medicago sativa*), common bean (*Phaseolus vulgaris*), clover (*Trifolium* spp.), and broad bean (*Vicia faba*), e. t. c. [26, 38]. The pathogen *Mycosphaerell a pinodes* is also reported to infect 13 genera of plants and more than 30 species, including all the above-listed crops and their wild relatives [66, 26]. As indicated in Table 2, Aschochyta blight-causing pathogens have their own distinuishing features.

Table 2. *Basal and distinguishing characteristics of pea ascochyta blight pathogens.*

Ascochyta blight Complex pathogen	Symptoms and diagnosis features	Distinguishing Features	References
Didymella pinodes	Leaf: initially appears as small purplish black spot; enlarged lesions are round to oval in shape contain brown concentric rings Seed: dark brown symptoms with discoloration at seed attachment position Stem: about blue black appearance at the lower stem areas and causes similar symptoms as *D. pinodes* but less severe on	The presence of pseudothecia Light buff spore mass oat meal agar (OA) medium Light buff spore masses on OA	[20]
Phoma medicaginis	More severe damage on leaves and pods observed as foot rot	Conidia are less than *D. pinodes* and A. pisi	[19]
Ascochyta pisi	Leaf: lesions are sunken, tan to light brown and surrounded by darker brown Stem: does not cause foot rot symptoms	Smaller black pycinida often appear on leaves Carrot red spore masses on OA and can't overwinter or survive in soil	[16] [17]

2.1.2. Disease Symptoms

Pathogens that cause Aschochyta blight can infect both above and below ground pea plant portions, and it can be very hard to differentiate them part based on field symptoms. This may include dark spore producing structures, discoloration on seed, and purple necrotic lesions on stems, tendrils, leaves, and pods [61, 54]. Thus, *A. Pinodes* can produce signs of *P. pinodella*, such as necrotic leaf spots, stem lesions and blackening, shrinkage and dark-brown seed discolouration, and foot rot in seedlings [17]. Under humid conditions, lower leaves, stems, and tendrils first show early symptoms like purple-brown irregular flecks, which lead to blight and leaf fall (Figure 3). The stem may girdle close to the soil line as result of severe infections; it may also girdle above and below the soil line. According to Anonymous [7], girdling lesions weaken the stem and increase the risk of lodging and yield loss. Lesions on pods can form and grow large enough to cause early pod senescence under extended damp conditions or if the crop has lodged [57b, 46].

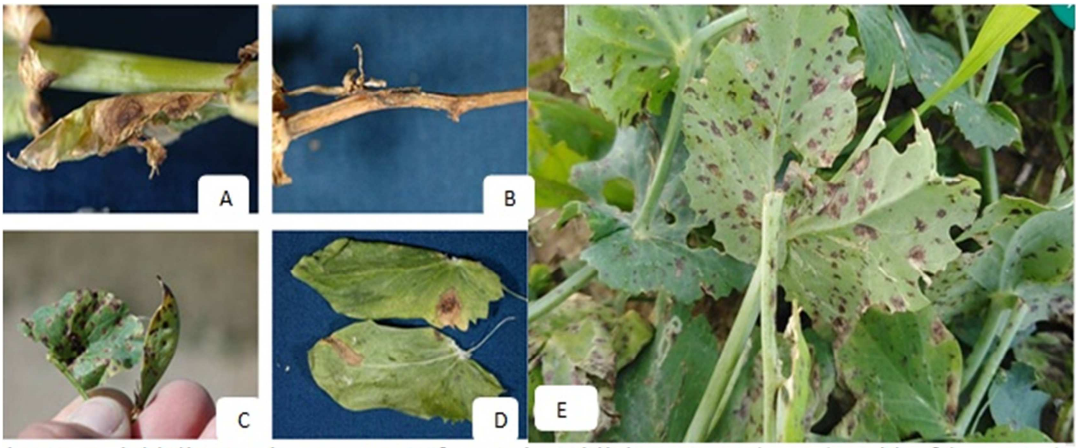

Figure 3. *Field diagnostic symptoms of Ascochyta blight on stem (A &B) and leaf (C, D, & E) lesions with concentric ring pattern.*

2.1.3. Distribution and Economic Importance

Ascochyta blight (black spot) is the most severe foliar disease of cool-season pulse crops, including field pea, chickpea, faba bean, and lentil, in severe epidemics that can cause total crop failure. It is distributed worldwide in temperate areas (Europe, North America, Australia, and New Zealand) and subtropical areas of Africa, Central America, and South America, where it is produced in large amounts [20]. The disease can cause 30–75% yield loss, and when it gets favorable environmental conditions, it can cause up to 100% loss [67]. According to Liu et al.'s [46] report, the disease is the most important in Australia, France, and Canada, with 60, 40, and 40–50% yield losses in the respective countries, respectively. In Ethiopia, too, it has extended to numerous pulses crop producing areas with a 20–30% average field loss report. Recently, Ogaji et al. [51] reported that ascochyta blight causes annual losses of about 50% in Canada, 40% in France, 30% in China, 72% in Spain, 10–60% in Australia, and 53% in Ethiopia.

2.1.4. Management Strategies

In order to increase and stabilize the yield of fields across the country, management of Ascochyta blight disease is crucial. Based on their importance, different options are recommended to manage the disease. This includes cultural practices (site selection, crop rotation, burial of infested crop residue with cultivation, using pathogen-free seed, etc.), the use of resistance varieties, and biological and chemical control.

(i). Cultural Practices

Are the most significant and successful management alternatives available in the field for reducing disease inoculum sources, and they comprise the following elements:

Crop rotation: Crop rotation (up to 3 to 4 years) is crucial to reducing or eliminating *Ascochyta blight* infections from a field since they can only live for a limited number of cropping seasons in diseased crop residue. The ascospores from infected residue (nearby fields) can serve as a significant inoculum to start an epidemic in the rotation regions, even while it has little effect on reducing *M. pinodes* or *P. pinodella* [73, 47]. This can significantly lower *A. pisi* and *P. medicaginis* inoculum levels within a field. In opposite to this, Khant et al. [40] reported that crop rotation has little to no effect on the severity of blight symptoms which appear in every year. Bailey *et al*. [10] and Zhang *et al*. [73] also, stated that that crop rotation, tillage, and burial have also been significant in reducing *M. pinodes* pathogen epidemics at different levels.

Mixed cropping and the use of clean seeds: Is the one way of reducing disease pressure. Besides, sowing field pea together with faba bean is used to reduce Ascochyta blight disease in field pea. Keneni and Jarso [39] have reported that the infection due to Ascochyta blight can be reduced from 100% to 32% when planted field peas together with faba beans. The blight-free seeds lessen the source of inoculum. In the absence of seed treatment, however, seed should be held at least for one year when known to be severely infected [19, 53].

Avoidance (residue and the inoculum): blight pathogens infested soil and residue due to ascochyta serve as sources of inoculum for the next epidemics. The pathogens *D. pinodes* and *P. medicaginis* that have long-term soil-borne survival structures can produce chlamydospores that may keep them up for more than 5 years [42]. Hence, avoidance is one of the key components in controlling ascochyta blight. In such conditions (where ascospores are the major source of infection), residual burial is more effective and beneficial than crop rotation [14].

(ii). Host Resistance

This is the most important and sustainable way to manage diseases. So, the current interesting new approach is the selection of resistance lines against diseases to assess the plant's reaction to one or more of the toxins produced by the pathogens [24]. The toxic metabolites from pathogens like *M. pinodes* and *A. pisi* can be extracted and characterized, which are useful new tools for the selection of resistant germplasm in breeding programs. The reaction of field pea lines to Ascochyta blight is variable. Different studies in Ethiopia reported that most of the field pea genotypes showed susceptible reactions and some showed moderate resistance (Table 3) to ascochyta blight [9, 39]. A tolerant line develops the same high level of disease as a susceptible line but suffers less yield loss. The mechanism underlying this type of response could be a factor like stronger stems in the tolerant lines [27, 38, 45].

Table 3. *Promising field pea genotypes evaluated for Aschochyta blight with their mean disease score.*

Genotypes	Mean disease (1-9 ss)	The reaction /Response/
GPHA-03	3.1	MR
GPHA-019	4.5	MR
GPHA-06	4.3	MR
GPHA-01	4.3	MR
GPHA-018	4.3	MR
GPHA-018	4.3	MR
P -313-010	4.0	MR
P -313-045	4.0	MR
P -313-086	3.8	MR
P -313-082	3.3	MR
P -313-071	4.0	MR
PDFPTBEK	3.3	MR
P -313-065	4.0	MR
P-313-098	3.8	MR
p-313-061	3.8	MR
p-313-068	3.3	MR
p-313-067	3.8	MR
EH 012022-1	4.0	MR
EH 012020-7	4.0	MR

NB: MR= moderately resistance, ss= scale score; Sources: [9]

(iii). Foliar Fungicides

Field pea crops are most susceptible to fungicide after the canopy closes, but at this stage, the lower leaves and stems become increasingly inaccessible to fungicide [29, 40]. A foliar fungicide application is an essential component of a disease management strategy that can be applied after sowing for the control of *D. pinodes* seed infection. App-lication of fungicides is frequently not cost-effective, and attempts to create decision support systems to determine when fungicide application is necessary have failed [30, 22]. Gudero et al. [31] reported that the combined use of tolerant cultivars with Othello, matico, and carbochlor successfully lessens the effects of Aschochyta blight.

2.2. Powdery Mildew

2.2.1. Pathogen Epidemiology and Host Ranges

Erysiphe pisi that cause fungal disease “powdery mildew” is a very major threat to field pea production today. It is an airborne or seed-borne obligate fungus that overwinters on infected pea trash and produces spores, which are blown by wind into new crops on warm and dry days enough for dew formation [62]. Under favorable environmental conditions, it can completely colonize a plant in 5 to 6 days. Once a few plants become infected, the disease rapidly spreads to adjacent areas. Disease development can easily be effective in warm (15–25°C) and humid (over 70 percent RH) conditions for 4–5 days late in the growing season, during flowering and pod filling stages.

Because the disease's spores are washed away from plant tissue by rain and are unable to spread infection, it has a smaller impact in locations with high rainfall. However, it was noted that the disease had severe impact on late sown and off season fields [75]. In a nutshell, the conidia from superficial conidiophores or ascospores are the main dispersal for propagules of powdery mildew (Figure 4), and they can cause breathing and allergy issues for machinery operators as well as damage to late-planted or late-maturing varieties. Accordingly, the harm is more severe the earlier the disease manifests itself [15].

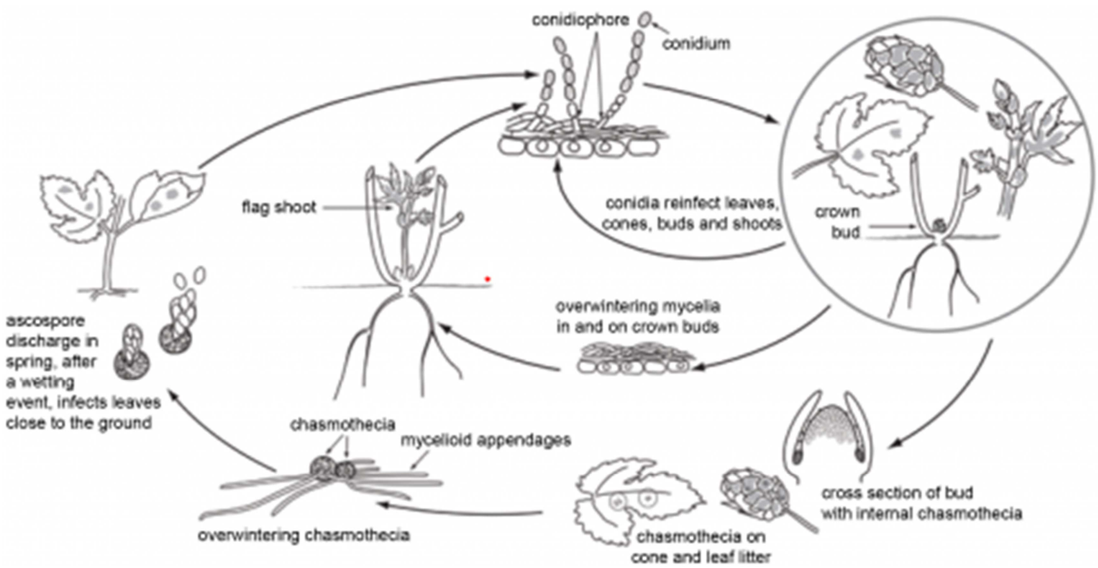

Figure 4. *Disease cycle of powdery mildew.*

Powdery mildews and their host plant are capable of long-term, dynamic co-evolution that leads to co-speciation. Rapid angiosperm diversification and the split of powdery mildews from a saprotrophic fungus in the Myxotrichaceae family that colonizes plant waste both resulted in host-specific fungi within the Ascomycetes [15].

Internal transcribed spacer sequences from the rDNA can be used to distinguish to differentiate Erysiphe species from *E. pisi*, together with an analysis of morphological traits such appendages. In *E. pisi*, it is normally mycelioid, whereas in *E. trifolii* and *E. baeumleri,* it is dichotomously branched. *E. trifolii* differs from *E. baeumleri* by having appendages that are pigmented and stretch out horizontally. Additionally, they can infect field peas at both in the field and in the glasshouse, conditions [52, 8]. Numerous plants that have been affected by powdery mildews in larger areas include artichokes, beans, beets, carrots, cucumbers, eggplant, lettuce, melons, parsnips, peas, peppers, pumpkins, radicchio, radishes, squash, tomatillos, tomatoes, turnips, etc. [5].

2.2.2. Disease Symptoms

Figure 5. *Diagnostic symptoms of powdery mildew on the leaves and podes of field pea; Source: Villegas et al. [69].*

Powdery mildew affects all green parts of pea plants. The first symptoms are small, diffuse spots on leaflets and stipules, usually first appearing on the lowest part of the plant as white powdery spots and spreading over large areas of the plant. Then lesions can grow and become white to pale gray powdery areas, which later coalesce and completely cover the plant surfaces (Figure 5). It can hasten crop maturity, rapidly raising tenderometer values beyond optimal green pea harvesting levels [72]. Under severe infections, it causes seed discoloration, downgrades seed quality, damages pea processing quality, leads to bitter characteristic and can cost hundreds of millions of dollars to control [75]. In all, the growth of a white, powdery, dust like layer on the surface of the leaves, and less frequently o the petioles of the leaves, stems, and podes, is characteristic of powdery [69]. The leaves are yellowed, dwarfed, and occasionally noticeably deformed.

2.2.3. Distribution and Economic Important

Powdery mildews are very diverse and complicated and have a biotrophic nature; they are widely distributed and detrimental plant diseases that affect a variety of economically important crops, such as field peas. This may contain more than 900 species and infect about 10,000 angiosperm species [43, 48].

Powdery mildews have a cosmopolitan distribution, occur in various biomes worldwide, and are becoming the world's most serious disease affecting field pea production. But a high distribution of powdery mildew is found in the temperate zone compared to humid tropical areas, where it causes up to 50–86% loss in field pea growth in different parts of the world [50]. In locations of moderate severity at mid altitude, powdery mildew has been observed to reduce the yield of field pea upto 20-30% [60]. This can be explained by the severe adaptation to dry heat that powdery mildews have experienced as a result of the deletion of genes encoding hydrophobins. The disease causes 25 to 50% average yield losses [36], and up to 21-37% yield losses have been documented in Ethiopia [65, 72]. It also decreases total yield biomass, number of pods per plant, number of seeds per pod, and plant height [36].

2.2.4. Management Options

(i). Cultural Practices

Rain can control the disease by washing away the spores. The most common practice to escape powdery mildew infection is to plant early in the growing season or use early-maturing cultivars. Early-sown crops and early maturing cultivars are often less affected by this disease than late-harvested crops because the fungus has less time to spread and affect yield. Most powdery mildew infections increase with soil nitrogen availability due to its effect on host growth rate, while phosphorous reduces the incidence of the disease [35]. Powdery mildew is often more severe in a lush pea stand. The fact that powdery mildew is more severe in conditions that favor growth and productivity of the host implies that crop management practices to create sub-optimal host growing conditions in the hope of reducing powdery mildew and its severity are not an attractive proposition for farmers [11].

Shade and mild temperatures are ideal for powdery mildews. So, locating plants in sunny areas that can provide good ventilation, avoid excess fertilizing, or use a slow-release fertilizer is very important. The washing of the powdery mildew pathogen spore via overhead sprinkling and crop separation in time and space can reduce and delay its spread and epidemics, respectively. In the incidence of powdery mildew, focusing more on weather factors than tillage regime is very important [48].

(ii). Host Resistance

Genetic resistance is quite an effective strategy for disease management, as it is both cost-effective and environmentally friendly. The genetics of powdery mildew resistance in peas are relatively well understood, with three major reported loci: Er1, Er2, and Er3. Different modes of inheritance (single recessive, single dominant, and duplicate recessive gene action) have been reported for powdery mildew resistance [55]. One dominant (Er3) and two recessive (Er1 and Er2) genes for resistance to powdery mildew have been found in the *P. sativum* germplasm. The gene Er1 is frequently employed in pea breeding programs and offers full to moderate degrees of resistance [27].

As the recent report indicated, resistance provided by er1 is due to a loss of function of the Mildew Resistance Locus "O" gene, while er2 confers complete resistance that is effective in some locations but ineffective in others [33]. This suggests the existence of races of *E. pisi*, but races of *E. pisi* have not been described unambiguously to date. The reaction of pea genotypes to powdery mildew in divergent locations in North and South America and Asia was similar. Gene Er3 was recently identified in *Pisum fulvum* and has been successfully introduced into adapted *P. sativum* material by sexual crossing [27].

In susceptible pea genotypes, *E. pisi* conidia germinate, producing a germ tube with a lobed primary aspersorium. A penetration peg emerges from this aspersorium and penetrates the epidermal host cells through the cuticle and cell wall. Furthermore, a primary haustorium forms within the epidermal cell. Nutrient uptake from the plant cell through the haustorium supports the development of secondary hyphae that radiate across the host epidermis, forming hyphal appersoria from which secondary haustoria are formed [62].

Table 4. *Resistance and Moderately resistance field pea genotypes screened against powdery mildew (Erysiphe polygoni).*

Genotype	Mean disease score (0-9 scale)	Response	Genotype	Mean disease score (0-9 scale)	Response
GPHA-14	4	MR	GPHA-28	3	R
GPHA-12	2.5	R	GPHA-59	3	R
GPHA-55	4	MR	GPHA-27	4	MR
GPHA-9	3	R	GPHA-53	4	MR
GPHA-22	2.5	R	GPHA-30	4	MR
GPHA-61	3	MR	GPHA-63	4	MR
GPHA-44	3	R	GPHA-46	2.5	R
GPHA-19	3	R	GPHA-24	3	R
GPHA-26	4	MR	GPHA-47	4	MR
GPHA-43	3	MR	GPHA-40	4	MR
GPHA-29	4	MR	GPHA-64	4	MR
GPHA-54	4	MR	GPHA-56	4	MR
GPHA-45	3	MR	GPHA-15	4	MR
GPHA-18	4	MR	GPHA-1	4	MR
GPHA-38	4	MR	GPHA-8	4	MR
GPHA-68	3	R	GPHA-13	4	MR
GPHA-2	3	MR	GPHA-11	4	MR
GPHA-58	2.5	R	GPHA-42	4	MR
GPHA-60	3	MR	GPHA-48	4	MR

Sources: Assen [9]

(iii). Chemical Control

The cost of repeated protective fungicide applications precludes their extensive use in many countries. Hence, the reactive program (fungicide application only when disease is observed) and the preventative program (routine applications) are more realistic and cost-effective. Fungicide must be applied when the number of plants infected is still low and the infection level on each plant is minimal (<5% infection). Success is dependent on effective monitoring and timely application. Pea growers are reluctant to follow a spray schedule requiring delivery of chemicals through ground rigs at late stages of crop development since crop damage is not compensated by yield increases. Recently, fungicides such as Tebuconazol, Propiconazole, and Triadimefon have been reported as effective chemicals for the control of powdery mildew, with 81, 78, and 68% disease reduction, respectively [6,1].

Generally, pesticide application is required if infection comes very early and/or conditions conducive to infection persist. In this case, follow-up applications and preventative programs are more appropriate when powdery mildew is known to occur regularly. The first spray should be applied at flowering, followed by additional sprays at 14-day intervals, depending on disease presence. Extensive research throughout the agrochemical industry has expanded options for powdery mildew control. These have proven very effective in controlling pea powdery mildew [71]. Triazole is reputed to have some translaminar systemic activity and is suited to the low-volume aircraft applications favored by green pea growers. A single Triadimefon application at early flowering prevents mildew infection of pods, increases yield, and evens out maturity, thus improving crop quality. Before using any chemicals, check that they are currently registered for use.

(iv). Biological Control

The idea of biocontrol has focused on important technological, economic, and political debates aiming to develop sustainable agriculture at a lower ecological cost. Thus, different countries have put into practice protective plans to reduce pesticide use by about 50% by substituting the application of biocontrol agents. Promising achievements have come into view after the successful use of certain antagonists [44]. Among these, Trichoderma spp. has been gaining worldwide interest for the control of diseases such as powdery mildew, which remains a challenge for future research and development [23]. The successful biological control methods of mildews by fungal and bacterial antagonists have been observed to have promising results for practical biocontrol, but more efforts are needed to prove the efficacy of these methods in agricultural practice. Attempts have been made to control powdery mildew with mycolytic bacteria, fungi, mycophagous yeasts, and other possible non-fungal biological control agents [4, 58]. Bacillus subtilis and Pseudomonas sp. are among the most promising biological control trials and have involved a number of antagonists by inhibiting the spores' germination and disrupting germ tube and mycelial development (Figure 6) of fungal and bacterial pathogens [74].

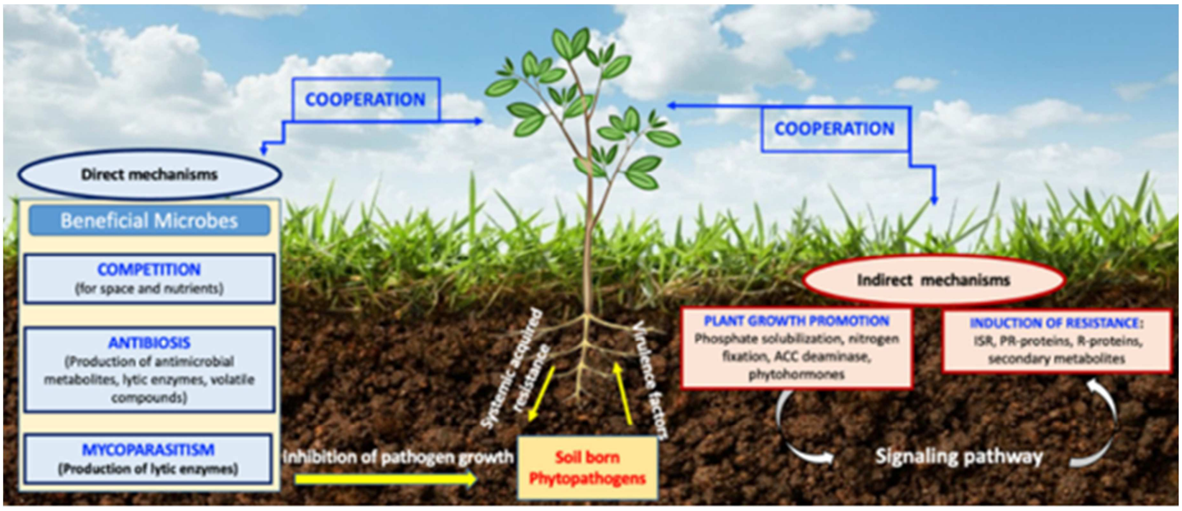

Figure 6. *Mode of action of biocontrol agents, Source: Zhu et al. [74].*

3. Summary and Conclusion

Despite the fact that field pea is a significant crop that improves soil quality and contributes significantly to human nutrition, its' yield is suffering globally due to a number of diseases such Aschochyta blight, powdery and downy mildews, Fusarium wilts, rust, etc. The Aschochyta blight and powdery mildew are currently the two biggest obstacles to Ethiopia's field pea production. Worldwide reports of Aschochyta blight and powdery mildew-related yield losses range from 30 to 75 and 50 to 86%, respectively. In Ethiopia, losses of 20–30 and 21–37%, respectively, have been observed. Under favorable environmental circumstances, they are capable of causing up to 100% damage.

It is imperative to create a various alternatives for managing such various diseases that threaten field pea output. Understanding these diseases' outbreaks and symptoms must come first in order to find the best and earliest cures. Options for managing diseases include cultural, host resistance, biological, and pharmacological approaches. The optimal solution must also result from the fusion and interaction of IDM strategies, also known as cultural, host resistance, chemical, and biological control strategies. Future disease management approaches should focus on the development and application of biopesticides and botanical control into consideration rather than the overuse of chemicals. Finding ecologically secure methods to prevent plant diseases is also encouraged by concerns for human health.

Acknowledgements

The authors would like to extend their sincere gratitude to all the people and academics that provided the references for this review.

References

[1] Abayechew, D., Guteta, N. and Wariyo, A., 2022. Efficacy of Fungicides against Powdery Mildew (*Pseudoidium jatrophae*) at Alage and Koka Districts of Ethiopia. *J Plant Pathol Microbiol*, *13*, p. 623.

[2] Abo Ertiro, T., 2020. Genetic variability and traits association among field pea *(pisum sativum l.)* genotypes evaluated at Asasa and Bekoji, south east highlands of Ethiopia (Doctoral dissertation, Haramaya University).

[3] Ahmed, H., Chang, K. F., Hwang, S. F., Fu, H., Zhou, Q., Strelkov, S., Conner, R. and Gossen, B., 2015. Morphological characterization of fungi associated with the ascochyta blight complex and pathogenic variability of *Mycosphaerella pinodes* on field pea crops in central Alberta. *The Crop Journal*, *3* (1), pp. 10-18.

[4] Ahmed, H. F., Seleiman, M. F., Al-Saif, A. M., Alshiekheid, M. A., Battaglia, M. L. and Taha, R. S., 2021. Biological control of celery powdery mildew disease caused by Erysiphe heraclei DC in vitro and in vivo conditions. *Plants*, *10* (11), p. 2342.

[5] Ale-Agha, N., Boyle, H., Braun, U., Butin, H., Jage, H., Kummer, V. and Shin, H. D., 2008. Taxonomy, host range and distribution of some powdery mildew fungi (Erysiphales). *Schlechtendalia*, *17*, pp. 39-54.

[6] Andualem, M., Zegeye, W., Asaye, G., Dires, G., Birhanie, M. and Legesse, Z., 2020. Fungicidal Management of Field Pea (Pisum sativam L.) Powdery Mildew (*Erysiphe polygoni* DC) Disease. *Abyssinia Journal of Science and Technology*, *5* (2), pp. 29-37.

[7] Anonymous. 2008. Ascochyta blights of field peas. Online. Ministry of Agric., Gov. of Saskatchewan, Regina, SK, Canada.

[8] Attanayake, R. N., Glawe, D. A., McPhee, K. E., Dugan, F. M. and Chen, W., 2010. Erysiphe trifolii–a newly recognized powdery mildew pathogen of pea. *Plant pathology*, *59* (4), pp. 712-720.

[9] Assen, K. Y., 2020. Response of Field pea (*Pisum sativum* L.) Genotypes to Ascochyta Blight (*Mycosphaerella pinodes*) disease in Arsi highlands, Southeastern Ethiopia. *EPH-International Journal of Science and Engineering (ISSN: 2454-2016)*, *6* (4), pp. 01-12.

[10] Bailey, K. L., Gossen, B. D., Lafond, G. P., Watson, P. R. and Derksen, D. A., 2001. Effect of tillage and crop rotation on root and foliar diseases of wheat and pea in Saskatchewan from 1991 to 1998: Univariate and multivariate analyses. *Canadian Journal of Plant Science*, *81* (4), pp. 789-803.

[11] Ball BC, Bingham I, Rees RM, Watson CA, Littlerock A., 2005. The role of crop rotations in determining soil structure and crop growth conditions. *Canadian Journal of Soil Science* 85, 557–577.

[12] Barilli, E., Cobos, M. J. and Rubiales, D., 2016. Clarification on host range of Didymella pinodes the causal agent of pea Ascochyta blight. *Frontiers in plant science*, *7*, p. 592.

[13] Berhane, T. M., Levy, J., Krekeler, M. P. and Danielson, N. D., 2016. Adsorption of bisphenol A and ciprofloxacin by palygorskite-montmorillonite: effect of granule size, solution chemistry and temperature. *Applied Clay Science*, *132*, pp. 518-527. 83.

[14] Bowness, R., Gossen, B. D., Chang, K. F., Willenborg, C. J., Conner, R. L. and Strelkov, S. E., 2021. Effect of fungicide application technology on seed yield in field pea under variable Mycosphaerella blight pressure. *Canadian Journal of Plant Pathology*, *43* (5), pp. 680-693.

[15] Bradshaw, M., 2020. Epidemiology and biology of powdery mildews and their host plants. University of Washington, pp 1-10.

[16] Bretage, T. W., Keane, P. J. and Price, T. V., 2006. The epidemiology and control of ascochyta blight in field peas: a review. *Australian Journal of Agricultural Research*, *57* (8), pp. 883-902.

[17] Chilvers, M. I., Rogers, J. D., Dugan, F. M., Stewart, J. E., Chen, W., and Peever, T. L. 2009. *Didymella pisi* sp. nov., the teleomorph of *Ascochyta pisi*. *Mycol. Res*. 113: 391-400.

[18] CSA (Central Statistics Agency), 2020. The Federal Democratic Republic of Ethiopia Central statistical agency agricultural sample survey, Pp39.

[19] Davidson, J. A. and Kimber, R. B., 2007. Integrated disease management of ascochyta blight in pulse crops. In *Ascochyta blights of grain legumes* (pp. 99-110). Springer, Dordrecht.

[20] Davidson, J. A., 2012. Epidemiology and management of *ascochyta blight* of field pea *(Pisum sativum)* in South Australia (Doctoral dissertation).

[21] Davidson, J. A., Krysinska-Kaczmarek, M., Wilmshurst, C. J., McKay, A. and Scott, E. S., 2011. Distribution and survival of ascochyta blight pathogens in field-pea-cropping soils of Australia. *Plant disease*, *95* (10), pp. 1217-1223.

[22] Davidson, J. A., Walela, C., Day, S., Roberts, P. and McMurray, L., 2022. Evaluation of economic fungicide strategies for control of ascochyta blight in field pea in southern Australia. *Australasian Plant Pathology*, *51* (5), pp. 495-505.

[23] Elsharkawy, M. M., Kamel, S. M. and El-Khateeb, N. M., 2014. Biological Control of Powdery and Downy Mildews of Cucumber Under Greenhouse Conditions. *Egyptian Journal of Biological Pest Control, 24* (2).

[24] Ertiro, T. A. and Haile, G. A., 2022. Field pea Production and constraints in the Highlands of Ethiopia a Review Article, pp: (59-71).

[25] Esmaeili Taheri, A., Chatterton, S., Foroud, N. A., Gossen, B. D. and McLaren, D. L., 2017. Identification and community dynamics of fungi associated with root, crown, and foot rot of field pea in western Canada. *European Journal of Plant Pathology*, *147* (3), pp. 489-500.

[26] Farr, D. F., Rossman, A. Y., Palm, M. E., and McCray, E. B. 2010. Fungal Databases. Online. Systematic Mycology and Microbiology Laboratory, USDA-ARS, Washinton, DC.

[27] Fondevilla, S., Rotter, B., Krezdorn, N., Jüngling, R., Winter, P. and Rubiales, D., 2014. Identification of genes involved in resistance to Didymella pinodes in pea by deep Super SAGE transcriptome profiling. *Plant molecular biology reporter*, *32* (1), pp. 258-269.

[28] Gebreslassie, B. and Abraha, B., 2016. Distribution and productivity of Dekoko (*Pisum sativum* var. abyssinicum A. Braun) in Ethiopia. *Glob J Sci Front Res Biol Sci*, *16*, pp. 45-57.

[29] Gorfu, D. and Sangchote, S., 2005. Fungi associated with field pea seeds from Ethiopia and seed transmission of Ascochyta pinodes. *Seed Science and Technology*, *33* (2), pp. 387-396.

[30] Gossen, B. D., Peng, G., Wolf, T. M., and McDonald, M. R. 2008. Improving spray retention to enhance the efficacy of foliar applied disease and pest management products in field and row crops. Can. J. Plant Pathol. 30: 505–516.

[31] Gudero Mengesha, G., Terefe, H., Yae, A. J., Arato, A. A., Betire, M. G., Samuel Shago, T., Bires, Z. F., Borano, B. B. and Abebe, S. M., 2022. Integration of host resistance and fungicides reduced ascochyta blight pressure and minimised yield loss in field pea (*Pisum sativum* L.) in southern Ethiopia. *Acta Agriculturae Scandinavica, Soil & Plant Science*, *72* (1), pp. 971-986.

[32] Gufi, Y., Tsegay, A., Ruelle, M. L., Teka, K., Tewold Berhan, S. and Power, A. G., 2022. Field pea diversity and its contribution to farmers' livelihoods in northern Ethiopia. *Legume Science*.

[33] Humphry M, Reinstädler A, Ivanov S, Bisseling T, Panstruga R., 2011. Durable broad-spectrum powdery mildew resistance in pea er1 plants is conferred by natural loss-of-function mutations in PsMLO1. Mol Plant Pathol doi: 10.1111 /J.13 64-3703.2011.00718.

[34] Hwang, S. F., Conner, R. L., Chang, K. F., Gossen, B. D., Su, H., Howard, R. J. and Turnbull, G. D., 2006. Impact of seeding rate and depth on Mycosphaerella blight and seed yield of field pea. *Canadian Journal of Plant Science*, *86* (3), pp. 845-853.

[35] Jarvis WR, Gubler WD, Grove GG., 2002. Epidemiology of powdery mildews in agricultural pathosystem. In: Bélanger RR, Bushnell WR, Dik AJ, Carver TLW (eds) The powdery mildews, a comprehensive treatise. APS Press, St. Paul, pp 169–199.

[36] Jha A. C., Sonika J., Reena, Anil. and Parmendra S., 2019. Loss Assessment caused by Economically Important Pea (Pisum sativum L.) Diseases and their Management in Hills of Doda (Jammu & Kashmir) under Field Condition, pp 170-176.

[37] Kebede, E., 2020. Grain legumes production and productivity in Ethiopian smallholder agricultural system, contribution to livelihoods and the way forward. *Cogent Food & Agriculture*, *6* (1), p. 1722353.

[38] Keirnan, E. C., Davidson, J. A., Correll, R. L. and Scott, E. S., 2020. Host range investigation of Phoma koolunga, a causal agent of ascochyta blight of field pea. *Australasian Plant Pathology*, *49* (6), pp. 707-719.

[39] Keneni, G. and Jarso, M., 2008. Performance of Released Faba Bean and Field Pea Varieties for Important Traits under Sole and Mixed Cultures III. Diseases incidence. *Trop. Agric*, *41* (3216), pp. 010065-009.

[40] Khan, T. N., Timmerman-Vaughan, G. M., Rubiales, D., Warkentin, T. D., Siddique, K. H. M., Erskine, W. and Barbetti, M. J., 2013. Didymella pinodes and its management in field pea: challenges and opportunities. *Field Crops Research*, *148*, pp. 61-77.

[41] Khani, M., 2015. Aspects of epidemiology of Phoma koolunga (ascochyta blight of field pea) (Doctoral dissertation).

[42] Khani, M., Davidson, J. A., Sosnowski, M. R. and Scott, E. S., 2016. Survival, transmission and control of Phoma koolunga in field pea seed and reaction of field pea genotypes to the pathogen. *Australasian Plant Pathology*, *45* (1), pp. 91-102.

[43] Kiss, L., Vaghefi, N., Bransgrove, K., Dearnaley, J. D., Takamatsu, S., Tan, Y. P., Marston, C., Liu, S. Y., Jin, D. N., Adorada, D. L. and Bailey, J., 2020. The recent introductions and multiple hosts range expansion events to the rediscovery of Salmonomyces as a new lineage of the Erysiphales. *Frontiers in microbiology*, *11*, p. 1571.

[44] Lahlali, R., Ezrari, S., Radouane, N., Kenfaoui, J., Esmaeel, Q., El Hamss, H., Belabess, Z. and Barka, E. A., 2022. Biological control of plant pathogens: A global perspective. *Microorganisms*, *10* (3), p. 596.

[45] Lee, R. C., Grime, C. R., O'Driscoll, K., Khentry, Y., Farfan-Caceres, L., Tahghighi, H. and Kamphuis, L. G., 2022. Field pea (*Pisum sativum* L.) germplasm screening for seedling ascochyta blight resistance and genome wide association studies reveal loci associated with resistance to *Peyronellaea pinodes* and *Ascochyta koolunga*. *Phytopathology*,

[46] Liu, N., Xu, S., Yao, X., Zhang, G., Mao, W., Hu, Q., Feng, Z. and Gong, Y., 2016. Studies on the control of Ascochyta blight in field peas (Pisum sativum L.) caused by *Ascochyta pinodes* in Zhejiang Province, China. *Frontiers in microbiology*, *7*, p. 481.

[47] McDonald, G. K. and Peck, D., 2009. Effects of crop rotation, residue retention and sowing time on the incidence and survival of ascochyta blight and its effect on grain yield of field peas (Pisum sativum L.). *Field crops research*, *111* (1-2), pp. 11-21.

[48] Mieslerova, B., Cook, R. T., Wheater, C. P. and Lebeda, A., 2022. Ecology of Powdery Mildews–Influence of Abiotic Factors on their Development and Epidemiology. *Critical Reviews in Plant Sciences*, *41* (6), pp. 365-390.

[49] Mihiretu, A. and Assefa, N., 2019. Comparative evaluation and demonstration of field pea production practices in intermediate altitudes of Northeastern Amhara, Ethiopia. *Turkish Journal of Agriculture-Food Science and Technology*, *7* (11), pp. 1901-19 07.

[50] Nisar M, Ghafoor A, Khan MR, Qureshi AS (2006). Screening of Pisum sativum L. germplasm against Erysiphe pisi. Botany 48 (2): 33-37.

[51] Ogaji, Y. O., Lee, R. C., Sawbridge, T. I., Cocks, B. G., Daetwyler, H. D. and Kaur, S., 2022. De Novo Long-Read Whole-Genome Assemblies and the Comparative Pan-Genome Analysis of Ascochyta Blight Pathogens Affecting Field Pea. *Journal of Fungi*, *8* (8), p. 884.

[52] Ondrej M, Dostálová R, Odstrčilová L, 2005. Response of Pisum sativum germplasm resistant to *Erysiphe pisi* to inoculation with *Erysiphe baeumleri*, a new pathogen of peas. Plant Prot Sci 41: 95–103.

[53] Pande, S., 2009. Integrated foliar diseases management of legumes.

[54] Parihar, A. K., Dixit, G. P., Bohra, A., Sen Gupta, D., Singh, A. K., Kumar, N., Singh, D. and Singh, N. P., 2020. Genetic Advancement in dry pea (*Pisum sativum* L.): retrospect and prospect. In *Accelerated Plant Breeding, Volume 3* (pp. 283-341). Springer, Cham.

[55] Rana, C., Sharma, A., Rathour, R., Bansuli, Banyal, D. K., Rana, R. S. and Sharma, P., 2023. In vivo and in vitro validation of powdery mildew resistance in garden pea genotypes. *Scientific Reports*, *13* (1), p. 2243.

[56] Salam, M. U., Galloway, J., Diggle, A. J., MacLeod, W. J. and Maling, T., 2011a. Predicting regional-scale spread of ascospores of Didymella pinodes causing ascochyta blight disease on field pea. *Australasian Plant Pathology*, *40* (6), pp. 640-647.

[57] Salam, M. U., MacLeod, W. J., Salam, K. P., Maling, T. and Barbetti, M. J., 2011b. Impact of climate change in relation to ascochyta blight on field pea in Western Australia. *Australasian Plant Pathology*, *40* (4), pp. 397-406.

[58] Sellitto, V. M., Zara, S., Fracchetti, F., Capozzi, V. and Nardi, T., 2021. Microbial biocontrol as an alternative to synthetic fungicides: Boundaries between pre-and postharvest applications on vegetables and fruits. *Fermentation*, *7* (2), p. 60.

[59] Sharma, K. K., Sharma, L., Rana, D. S., Sharma, G., Rawat, S. and Sharma, P., 2022. Current Status of Vegetable Pea (Pisum Sativum Var. Hortense) Diseases and Their Management Strategies. In *Diseases of Horticultural Crops* (pp. 523-544). Apple Academic Press.

[60] Singh, J., Dhall, R. K. and Aujla, I. S., 2015. Characterization of resistance response of garden pea (*Pisum sativum* L.) against powdery mildew (Erysiphe pisi DC) in sub-tropical plains of India. *Sabrao J. Breed. Genet*, *47*, pp. 384-393.

[61] Skoglund, L. G., Harveson, R. M., Chen, W., Dugan, F., Schwartz, H. F., Markell, S. G., Porter, L., Burrows, M. L. and Goswami, R., 2011. Ascochyta blight of peas. *Plant Health Progress*, *12* (1), p. 29.

[62] Smith PH, Foster EM, Boyd LA, Brown JKM,. 1996. The early development of *Erysiphe pisi* on *Pisum sativum* L. Plant Pathol.

[63] Teshome, A., 2015. *Pea weevil (Bruchus pisorum L.) resistance and genetic diversity in field Pea (Pisum sativum L.)* (No. 2015: 81).

[64] Teshome, A., Mendesil, E., Geleta, M., Andargie, D., Anderson, P., Rämert, B., Seyoum, E., Hillbur, Y., Dagne, K. and Bryngelsson, T., 2014. Screening the primary gene pool of field pea (*Pisum sativum* L. subsp. sativum) in Ethiopia for resistance against pea weevil (*Bruchus pisorum* L.). *Genetic Resources and Crop Evolution*, *62* (4), pp. 525-538.

[65] Teshome, E. and Tegegn, A., 2017. Comparative Study of Powdery Mildew (*Erysiphe polygoni*) Disease Severity and Its Effect on Yield and Yield Components of Field Pea (*Pisum sativum* L.) in the Southeastern Oromia, Ethiopia. *J Plant Pathol Microbiol*, *8* (410), p. 2.

[66] Tivoli, B. and Banniza, S., 2007. Comparison of the epidemiology of ascochyta blights on grain legumes. In *Ascochyta blights of grain legumes* (pp. 59-76). Springer, Dordrecht.

[67] Tran, H. S., 2017. Black spot disease complex in field pea–pathogens involved and interactions with host resistance.

[68] [USDA] United State Department of Agriculture. 2022. World agricultural production. Circular Series WAP 4–22, Foreign Agricultural Service, United State Department of Agriculture. pp. 37. https://apps.fas.usda.gov/psdonline/ circulars/ produ-ction.pdf

[69] Villegas-Fernández, Á. M., Amarna, A. A., Moral, J. and Rubiales, D., 2021. Crop diversification to control powdery mildew in pea. *Agronomy*, *11* (4), p. 690.

[70] Walters DR, Bingham IJ, 2007. Influence of nutrition on disease development caused by fungal pathogens: Implications for plant disease control. Annals of Applied Biology 151, 307–324.

[71] Warkentin, T. D., Smýkal, P., Coyne, C. J., Weeden, N., Domoney, C., Bing, D. J., Leonforte, A., Xuxiao, Z., Dixit, G. P., Boros, L. and McPhee, K. E., 2015. Pea. *Grain legumes*, pp. 37-83.

[72] Yimam, K., Robsa, A., Yilma, G. and Abo, T., 2020. Evaluation of Field Pea (Pisum sativum L.) genotypes for yield and yield attributing traits at high land of Arsi, South East Ethiopia. *Science Journal of Applied Mathematics and Statistics*, *8* (6), pp. 73-80.

[73] Zhang, J. X., Fernando, W. G. D. and Xue, A. G., 2005. Effect of residue type and burial depth on survival of Mycosphaerella pinodes in Manitoba. *Canadian Journal of Plant Pathology*, *27* (1), pp. 132-136.

[74] Zhu, L., Wang, Y., Lu, J., Liu, S., Min, Y., Liu, X., Qiu, Y., Hu, H. and Zhou, R., 2021. Complete genome sequence of *Bacillus badius* NBPM-293, a plant growth-promoting strain isolated from rhizosphere soil. *Microbiology Resource Announcements*, *10* (45), pp. e00977-21.

[75] Wspanialy, P. and Moussa, M., 2016. Early powdery mildew detection system for application in greenhouse automation. *Computers and Electronics in Agriculture*, *127*, pp. 487-494.