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Major fungal diseases of oilseed brassica and their preventive measures: A brief review

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Abstract
Brassica is one of the major sources of protein and oil for humans. It also serves as a promising source of allelochemical to control a variety of soil-borne pests. Various phytopathogens including bacteria, fungi, nematodes and viruses cause significant yield losses in storage and field conditions. The major fungal diseases are Alternaria leaf spot and blight (*Alternaria spp.*), Anthracnose (*Colletotrichum* spp.), Downy mildew (*Peronospora parasitica*), Powdery mildew (*Erysiphe cruciferarum*), Sclerotinia stem rot (*Sclerotinia sclerotiorum*), White rust (*Albugo candida*), Wilt (*Fusarium* spp.), Leaf spot (*Leptosphaerulina brassicae, Cercospora cheiranthi*), Damping-off (*Pythium* spp.), Clubroot (*Plasmodiophora brassicae*), Black leg (*Leptosphaeria maculans*). They are some of the most detrimental fungal diseases which causes huge crop loss including decrease in quantity, quality and market value. This review paper reveals the symptoms and management strategies against important fungal diseases affecting *Brassica*.

Keywords: *brassica*, crop loss, fungal diseases, symptoms, management strategies

Introduction

Brassicaceae family comprises about 3,000 species grouped in 350 genera [1]. Evidences show that some of the brassicas were commonly used in Neolithic age [2]. Rapeseed and mustard were cultivated in India as early as 1500 BC [3] In Brassicaceae family, Brassicas are the most economically noteworthy genus, which includes oilseed crops that yields high quality edible and industrial oil and forage crops that supplies common vegetables, weeds and condiments. Oilseed Brassicas are the third largest contributor to the world edible oil supply and India accounts as third largest producer of rapeseed and mustard (6.41 mt). The oilseed Brassicas include *Brassica napus, Brassica juncea*, *Brassica carinata* and *Brassica campestris (or Brassica rapa)* [4] while *Brassica* vegetables include leafy vegetables like cabbage, broccoli, cauliflower, kale, Brussels sprouts and turnip *etc.* Along with oil *Brassica nigra* is also used as condiment [5].

These crops are grown in tropical and temperate zones and prefer 30-60% relative humidity. These crops have a great adaptability of wide range of soils from sandy loam to clay loams. *Brassica* crops are erect branched 3' to 6' in height, annual plant with tapering and slender root. The stem is branched from the axil of the fourth or fifth leaf upward. Lower leaves are green and petioled, variously lobed with toothed or frilled edges, with 1-2 leaflets on each side. Upper leaves are short and petioled. The fruit is called siliqua. The pods are bilocular with a false septum between two halve.

These oil-yielding plants, possesses a variety of health benefitting properties. These contains ample amount of unsaturated fatty acid i.e. oleic acid (8-40 %), omega-6 fatty acid (lenolenic acid) (5-10 %), omega-3 fatty acid (linoleic acid) (10-29 %), eicosinoic acid (5-12 %), erucic acid (40-55 %) and the low concentration of saturated fatty acid (7%) [6]. It also contains protein (20-25 %), carbohydrate (14-16 %), fiber (10-15 %) [7], moisture (6-8 %), mineral (3-4 %), vitamins (0.7-0.9 %) glucosinolate (2-3 %), phytic acid (3-6 %), sinapine (1-1.5 %) and tannin (1.6-3.1 %) [8]. It possesses high levels of plant sterols, like β-sitosterol and campesterols which competitively inhibit cholesterol absorption and reduces cholesterol level by 10% to 15%. It is rich in natural antioxidants and Vitamin A, C and E [7].Mustard oil antifungal properties are due to the presence of substance like glucosinolate. It is also antibacterial in nature and fights against infections. It has various medicinal properties too as they contain a large number of phytochemicals, some of which protect against carcinogenesis [9]. The major factors which restrict oilseed Brassica productivity are non-availability of high yielding varieties appropriate for high input conditions, weather fluctuations and many biotic and abiotic stresses [10]. Main abiotic constraints are drought, salt, heat, frost and heavy metal stress. Flowering to pod formation stage is more prone to drought and frost whereas seedling stage is more prone to salt stress. More than 30°C atmospheric temperature proves detrimental to seedlings leading to mortality of germinating seedlings. Heavy metal stress induces various biochemical and physiological responses, which lead to reduced plant growth and development. It stimulates the formation of reactive oxygen species (ROS), disturbs the redox state and affects energy homeostasis of plants [11]. Besides abiotic stresses, biotic stresses which includes fungal diseases, [12] bacterial diseases [13], viral diseases, [14] nematodes, [15] and aphid pests [16] cause major yield loss in Brassicas. Fungal diseases play an important role in yield loss and are present at different stages of the plant growth from seedling to fruit stage. There are about thirty diseases which have been reported to occur on these crops [17]. Among all the infectious fungal diseases affecting crucifers (on the basis of yield losses and wide distribution) alternaria blight, white rust, sclerotinia stem rot, downy mildew and powdery mildew are considered to be most devastating. This review paper provides the information and management of important fungal disease which mostly attack Brassicaceae family all over the world.

Alternaria leaf spot and blight

Alternaria leaf spot and blight in *Brassica* plants are mostly caused by *Alternaria* species (*Alternaria brassicae*, *Alternaria brassicicola*, *Alternaria raphani*, *Alternaria alternata*). Almost 299 species are listed in this genus [18]. The pathogens have a wide spectrum of hosts including almost all crucifers. Host specificity varies in different species of *Alternaria* on *Brassica* species. *Alternaria* pathogens are soil-borne, air-borne and seed-borne [19]. Pathogens are most active in relatively high humid seasons and areas [20]. Distribution of *A. alternata* and *A. raphani* are widespread in the Northern hemisphere while *A. brassicae* and *A.brassicicola* are cosmopolitan [21]. Most of *Alternaria* species are saprophytic in nature and are commonly found in soil or on putrefying plant tissues. It proliferates vegetatively. Teleomorphy is rarely seen in *Alternaria.* It is most devastating disease of oil yielding brassicas. Spores of *Alternaria* are multicellular, pigmented and occur in branches or chain form. *Alternaria spores* are broad near the base and taper at the end forming an elongated chain like structure.

Alternaria usually causes spotting of leaves, damping-off of seedlings, root and foot rot. Infected seeds loose seedling vigor and power of germination which causes damping off. Black spots occurring on leaves, stems and siliquas accelerate the process of aging and reduce the area of photosynthesis in the plant. Infection not only turns down the fresh produce but also affects the stability of stored products. Infected seeds containing spores or mycelium on or under the seed coat are the main source of transport of these pathogens. Water, wind, animals and infected tools also causes spread of spores. Most of the infections occur due to the infected left over on the ground after harvest. This phytopathogen can also lie dormant on perennial plants, vulnerable weeds and crop debris [22].

All the four *Alternaria* species are reported to cause the basic symptoms on all the parts of the plant. Symptoms of *Alternaria* mainly includes light brown lesions which later on turns black due to the abundance of spores which turns to be the source of infection for other plant parts [23]. These lesions rapidly multiply and spread to other plant parts like stems and siliques etc. The black or brown spot contains visible circular, concentric rings. The circular spots often merge to form large patches causing the leaf blight. In severe attacks plant shows damping off of seedling, wilting and rotting at foot and root like symptoms also [24]. Host-selective toxins released by the pathogen facilitate necrosis which increases the severity of disease by decomposing the host cells using degrading enzymes [25]. For prevention of *Alternaria,* a combination of agricultural management practices and chemical protection should be applied. Conventional methods used to combat *Alternaria* includes timely sowing of clean [26], healthy and certified seed, maintaining a balanced nutrition, destruction of infected weed and left over debris, proper field sanitation, eluding irrigation at flowering and pod formation stages and crop rotation with non-cruciferous crops. Surface sterilization of seeds using sodium hypochlorite reduces growth of the *Alternaria*. Treating seeds with hot water also control seed-borne *Alternaria* infection. Chemical control is the second most extensively used means of crop protection against *Alternaria*. All the fungicides significantly affect the reduction in disease severity and increase in seed yield [27]. A number of fungicides have been reported to be effective against the spread of against *Alternaria* under different field conditions *e.g.* Dithane M-45 (0.2%), Dithane Z-78 (0.2%), Iprodione (Rovral) (0.2%), Blitox 50 (0.3%), Baycor (0.2%) and Mancozeb (64%) [27-30].

The chemical control leads to residual toxicity, destroy non-target microflora, affects the oil quality of oilseed and develops resistance in the target organisms. Hence, biocontrolisd the alternative method, which suggest use of Mycostop (formulation of Streptomyces), soil amendments with isolate of of *Trichoderma virdie* [29] and bulb extracts of *Allium sativum* [31] which are found to be as effective as fungicides used without disturbing ecological balance. Increase in studies of plant-pathogen interactions and identification of various resistance sources has opened up the path of biotechnological approach. This includes introgression and over-expression of some Pathogenesis-related protein like chitinase [32], glucanase, defensins, peroxidase, proteinase inhibitors etc. which provide adequate resistance against pathogen attack. Other than this, use of biotechnological tools like *in vitro* embryo and ovary rescue, somatic hybridization, somaclonal variation, genetic transformation, use of molecular markers, protoplast fusion and induction of systemic resistance enables the development of *alternaria* tolerant/resistant varieties of *Brassica*.

Black leg

Black leg also known as dry rot is caused by *Leptosphaeria maculans.* It is an extremely destructive disease of crucifers worldwide. The fungus *L. maculans* infect all parts of the plant, including stem and leaves. Stem damage lead to cankering and severing of the plant at the base. It is the most serious symptom of the disease which causes plant lodging and yield loss [33]. Wet and windy conditions favor the development of the disease. Infected canola stubble serves as important source of inoculum of *L. maculans* which bears pseudothecia from which ascospores are released [34]. Besides the left over debris, it is also carried over by seeds which further get spread by irrigation, rain water splash, wind, farm machinery and equipment dispersing the spores from lesions.

Lesions exude a rose-pink spore mass during moist conditions. On leaves, black leg appears as small light brown lesions with a purplish outline. The lesions are linear and irregularly distributed on the leaves. On stems and bulbs, it appears as large brown-black dry and cracked lesions. As the disease develop further the bulbs crumple, leaves die and finally fall off and stems sever at the point of the lesion.

In some areas ascospores are discharged from lesions at the flowering stage, at which the plant is highly susceptible to the disease [35]. With the increase in temperature, light intensity and leaf wetness the rates of production and maximum number of sporulating bodies produced per leaf also increases, thereby increasing the risk and severity of the infection [36].

Before sowing field sanitation of infected crop debris should be ensured for good cultivation. Certified and disease free seeds should be used for sowing. Good crop rotations with non-host crops for three to five years showed decrease in trend of infection [37]. Use of *L. maculans* tolerant cultivars also reduces the prevalence of black leg in areas affected from severe infections. Brassinin a vital plant defense product, produced by crucifers is detoxified by the *L. maculans* to indole-3- carboxaldehyde using brassinin oxidase. Synthesis and characterization of detoxification inhibitors, which shows cytotoxic as well as antifungal activity, can be used in combating the phytopathogenic fungus *L. maculans*[38].

Clubroot

Clubroot is caused by soil-borne fungus *Plasmodiophora brassicae*, which is an obligate biotroph. It is one of the most devastating diseases of crucifers [39]. It is cosmopolitan in distribution. The pathogen induces swollen galls on root of the infected plants ranging from tiny nodules to large club-shaped outgrowths which interferes in water and nutrient uptake, resulting in yellowing of leaves, wilting, stunting, lodging and finally leading to yield loss.

Clubroot is capable of causing infection in the warmer months and can be spread through irrigation. The fungus can survive in soil for many years even without the presence of susceptible host. In presence of susceptible host, the spores germinate and release tiny motile spores which swim in water and after reaching the rootlets, penetrate the roots and form a fungal colony in the root cells. The pathogen causes the root cells to divide and enlarge rapidly, leading to the formation of galls. Later on spores develop in the infected root cells and get released into the soil as the galls decay.

The infection is restricted to the roots only and can occur at any stage of growth of the plant. It causes chlorosis, necrosis and abscission in leaves; accelerate the scheduled growth of flowers, resulting in formation of underdeveloped fruit carpels. Life cycle of *Plasmodiophora brassicae* completes in two phases. The first phase affects root hairs of the plants while the second phase distress the cortex of hypocotyls and roots where the cortical infection causes swelling, discoloration, disruption of vascular tissue and clubbing on roots [40]. During second phase the plasmodia provoke the host and neighboring cells to grow and divide further, producing hypertrophic conditions in the host tissue due to clustering and maturing of young plasmodia into groups. These plasmodia then differentiate into resting spores [41].

Since the resting spores can survive in soil for many years, so avoiding plantation of cruciferous crops in the soil infected with *Plasmodiophora brassicae* proves to be effective strategy for managing the disease. Good crop rotations, reduced soil tillage, good drainage, weed control; proper sanitation of farming equipment and maintaining high pH of soil by liming reduces the development of disease. Clubroot-resistant crops are also an effective method for controlling the disease, which can be utilized in agriculture raised by combining marker assisted selection, genetic engineering and traditional breeding. Clubroot resistant genes have been identified in *Brassica rapa*, *Brassica oleracea* and *Brassica napus*[42]. Biocontrol can be applied to plants to reduce pathogen inoculums. A strain of *Streptomyces griseoruber* isolated from the rhizosphere of Chinese cabbage reduced the severity of clubroot infection [43].

Chemical control which includes fungicides and certain surfactants like fluazinam, which is a protectant fungicide disrupts the oxidative phosphorylation of plant, and blocks primary and secondary infection of *P. brassicae* thereby reducing the severity of disease [44, 45]. Flusulfamide and cyazofamid restrain the germination of *P. brassicae* primary zoospore motility in soil. Non-ionic surfactants provide a chemical barrier against infection and reduce further growth of pathogen [46] Fumigation with metham sodium also reduces soil population of *P. brassicae* [44].

Damping-off

Damping-off is caused by the fungus *Rhizoctonia solani. Besides R. solani* other fungi like *Pythium spp*., *Phytophthora spp*., *Fusarium spp*., *Alternaria spp*. and *Leptosphaeria maculans* are also responsible for causing damping-off in brassicas. All these pathogens are grouped together and are common residents of soil therefore, symptoms and preventive measures are also similar for all of them. Damping off fungi have a wide range of host and they can even survive on alternative non-brassica hosts.

R. solani is a soil and seed borne pathogen linked with seed and root rot. It causes reduced germination and pre and post-emergence damping-off in seedlings leading to a poor plant stand. Mainly anastomosis groups AG2-1 and AG4 from *R. solani* infect rapeseed and mustard. Cool and moist weather is favored by AG2-1 in seedling infection whereas warm weather is required for infection of mature plants by AG4 isolates. Besides damp weather and temperature, soil moisture also affects the development of disease which varies with different anastomosis group. Wet, heavy soils favor *Pythium spp*. while loose, cold and dry soils favor *R. solani* and cold damp soils favors the growth of *Fusarium spp*.

Symptoms of damping-off ranges from failure of plants to emerge during seedling stage (pre-emergence rot) to crumpling of fully emerged plant at ground level (post-emergence damping-off). Infected plants usually show stunted growth with pre-scheduled flowering, leaves become chlorotic and discolored; tap root becomes dark in color and shrink at the ground level. Early infections are known as damping off and later are known as wire stem. In the absence of host damping-off fungi survive by forming resistant resting bodies in the soil. Being an opportunist, during favorable conditions the resting bodies germinate and grow through the soil till to find a host. The fungi enter the host plant through dry seeds, they start multiplying and damage the seedling, thereby killing it. Being weak pathogens damping-off fungi usually affect young succulent tissues.

Preventive measures include long crop rotation which reduces yield losses. Chemical control makes use of fungicides cyproconazole, carboxin, benodanil, pencycuron, fenpropimorph, iprodione, tolclofos-methyl etc. and some commercial formulations like iprodione 16.7% + lindane 50%, carbothiin 4.5% + thiram 9% + lindane 67.5% and thiabendazole 1.6% + thiram 4.8% + lindane 40%. Instead of powdered form, granular and slow release fungicide provide enduring disease control against damping off.

Biological control of pathogen includes a strain of *Pseudomonas fluorescens* producing phenazine carboxamide, pyocyanin and pyrrolnitrin antibiotic secretions which inhibit the growth of damping off pathogen [47]. Five bacterial strains of *P*. fluorescens, one of *Coryneform* group and one of *Enterobacter agglomerans* were found to be effective in suppressing the growth of *R. solani,* when applied as seed treatments in canola field [48] Vesicular arbuscular mycorrhizal plants restrain root infection caused by *R. solani* [49]. Use of *Trichoderma harzianum* (UPM40) not only improvise soil but also significantly control the growth of damping off pathogens in leaf mustard (*Brassica rapa* L.) [50]. Certain genotypes have been screened for resistance against damping-off caused by AG-2-1 strain of *R. solani* [51]. Transgenic plants containing bean endochitinase was found to be more resistant to *R. solani*, as compared to the plants that lack the chimeric chitinase gene [52] The enzyme inhibits the growth of *R. solani* by inducing changes in mycelial morphology and disrupting the hyphal tips. Besides biological and chemical barriers, plant's defense system also provides temporary resistance against damping off. Plants became less vulnerable with age as older plants showed low disease ratings [53]. Thicker cuticle act as mechanical barrier during infection and reduces the frequent chances of penetration thereby delaying the entry of pathogen into the host plant. Calcium content of host plant not only affects the permeability of cell membrane and pectin metabolism but also decreases the accessibility of certain micronutrients needed for the growth of pathogen [54] 10-methylsulfinyldecylisothiocyanate and methyl 1-methylindole-3-carboxylate antimicrobial compounds from roots; camalexin, phytoalexins and methoxycamalexin produced from leaves, stems, roots and siliquae of *Camelina sativa* inhibit the mycelial growth *of* AG2-1 strain of *R. solani* [55]

Downy mildew

Downy Mildew is caused by the fungus *Hyaloperonospora parasitica* formerly known as *Peronospora parasitica.* It is a common and destructive disease of *brassica* vegetables. It is extensively found in almost all parts of the world. Infection occurs during cool and moist conditions, when cotyledons or leaves come in contact with the soil or other infected leaves.

It can damage plant at any stage of growth from seedling, cotyledons to the harvest stage [56] The pathogen is both soil and seed-borne. It can survive in the soil for a long period. The main sources of infection are wind, crop debris or soil. Symptoms of disease emerge as chlorotic, yellow, irregular areas or lesions on the upper surface corresponding to a fluffy, white mass of spores on the underside of leaves. As the disease develop further, the individual lesions merge to form large irregular, extremely thin blotches which become dry and black-gray in color causing premature falling of leaves. The development of infection causes early leaf senescence, defoliation and reduced yield [57, 58]. The pathogen is often associated to white rust and most likely responsible for its primary infections. Spores produced on the bottom of the infected leaf extend the infection to secondary level.

Usually, Downy mildew does not affect the yield so much, therefore, preventive measures are not needed until disease affect the yield severely. Weed control, crop rotation and fungicides containing copper as the active element help in reducing the disease severity. Fungicides like mixture of cymoxanil and mancozeb; site specific fungicides like Carboxylic Acid Amides, Phenylamide and Quinone outside Inhibitors proved to be effective against downy mildew[59]. Some chemical formulations like mixture of 58% potassium phosphonate (K_2HPO_3) and 42% water at concentration 10 ml/l for young plants and 7.0 ml/L for seedlings found to be effective for a short period of time [59]. Production of resistant and susceptible varieties with the aid of genetic manipulations can also reduce the incidences of infection [60]. A dominant character controlled by a single locus *Pp523* inheriting resistance against downy mildew has been identified and mapped [61, 62]. Use of marker assisted selection in breeding programmes pointing towards the insertion of *Pp523* gene will become useful for providing resistance to the plant against downy mildew [51].

Powdery mildew

Powdery mildew is caused by the fungus *Erysiphe polygoni*. It is a common trivial disease of crucifers. It has been reported from several parts of the world. It occurs in late summer and autumn. Moderate to dry-warm weather and low relative humidity proves to be favorable for the growth of the pathogen. It infects all aboveground parts of the plant. The pathogen produces powdery fungal growth on adaxial and abaxial surface of leaf as a result of which leaves fall prematurely and become pale in color. Air-borne spores of *Erysiphe polygoni* survives winter on infected plants, crop debris or weeds and acts as the primary source of inoculums for this polycyclic disease [17]. In India yield losses at harvest, occurring due to the pathogen, reaches up to 17 % [63] total destruction of the crop is extremely rare in this case. Since the disease is not highly destructive so no control is required. Still to combat the disease a lot of effective fungicides are there. Cultivars resistant to powdery mildew are the best source of prevention of the disease.

Sclerotinia stem rot

Sclerotinia stem rot also known as white blight, stem disease or watery soft rot. It is mainly caused by pathogen *Sclerotinia sclerotiorum.* It is a ubiquitously necrotrophic pathogen and cosmopolitan in distribution. *Sclerotinia sclerotiorum* infects around 400 species of plants [64]. The pathogen affects a wide range of crops including beans, peas, sunflowers, lupins and weeds. But mainly it targets the yield of rapeseed-mustard at different phenological stages of plant growth thereby adding a huge amount of inoculums to the soil [65]. This disease is intermittent as infection occurs mostly in favorable environmental conditions. In some parts of India approx. 80 percent of disease incidence have been recorded [66, 67].

Source of infection is air-borne spores or sclerotia which act as dormant survival spores in the soil. Sclerotia can survive for many years in the soil. Humid (wet) conditions enhance germination of the spores and infection. *Sclerotinia sclerotiorum* has four stages in its life cycle: sclerotia, apothecium, ascospore and mycelium [68]. Germination of sclerotia in soil gives rise to mycelium which infects the susceptible plant. Sclerotia firstly invade nonliving organic matter and form a mycelium. Later on, apothecia develop from sclerotia which releases ascospores. These ascospores are airborne and descend on nonliving plant parts where they germinate, bifurcate the nonliving plants and invade healthy plants. Ascospores can infect the host by directly penetrating the healthy host tissues.

Symptoms of the disease appear two to three weeks post infection. The pathogen produces light brown faded patches on branches, stems and pods. These patches expand and become grayish-white in color. Infected plants look bleached as compare to healthy plants. The bleached plant parts tend to break and shred at the base. Infected stem split open to give hard black bodies called sclerotia which is the resting stage of the fungus. *Sclerotinia sclerotiorum* secretes oxalic acid (OA) into infected host tissues [69, 70],which act as mobile toxin and causes wilting syndrome in plants [71]. In case of *S. sclerotiorum* oxalic acid (OA) act as a pathogenicity factor which factor suppresses the hypersensitive response of the host plants [72]. For prevention of disease caused by *Sclerotinia sclerotiorum* good agricultural practices should be used like sowing certified seed which are disease free along with crop rotations. Infected left over debris and infected soil should be removed before sowing seeds. Several fungicides are also available to reduce the incidences of this disease. Transgenic approaches for combating sclerotinia pathogen includes detoxification of the pathogenicity factor OA (oxalic acid), inhibition of *S. sclerotiorum* growth by the use of antifungal proteins and activation of endogenous defense pathways.

White rust

White rust also known as white blister or staghead disease is caused by the pathogen *Albugo candida*. White rust is one of the major constraints responsible for low productivity of cruciferous species. The pathogen affects both domesticated and wild species of crucifers as it has a wide host range including about 29 genera of crucifers [73]. It is an obligate parasite. It is wide spread in almost all parts of the world. Possibly contaminated seeds and soil are the major source of dispersion of the pathogen. Cool and wet weather proves to be favorable for the development of this disease. The pathogen is characterized by infection caused on all the above ground tissues of their hosts. Primary infection occurs through the oospores present in soil or seeds. The pathogen produces white to cream colored zoosporangial pustules on young stem, leaves, cotyledons and inflorescences [74]. The pustules or blisters contain white spores which rupture the host epidermis dispersing a white chalky dust. Secondary infection occurs through readily airborne spores that release biflagellate, motile, infective zoospores [75]. These spores can be spread by infected produce, crop debris, water splash and wind. Systemic infection caused at the flowering stage resulting in severe inflorescence malformation is known as staghead [76]. *Albugo candida* causes both local and general infection which includes pustule formation undersides of leaves, chlorotic spots on the adaxial leaf surface, stems and pods as local infection while distortion, hyperplasia, hypertrophy and sterility of inflorescences (staghead) as general infection[77].

Preventive measures of white rusts include the use of healthy, certified and disease free seeds. Extended rotations provide enough time to decompose the crop residues which reduce the risk of infections. Keeping weed populations in control is extremely beneficial. As soon as the symptoms appear on the plant spray of Difolatan 0.2% helps minimizing the effect of disease. Biotechnological approach has opened a plenty of ways like producing resistant cultivars by introducing resistant genes, producing hybrids which are tolerant to white rust, development and authorization of AFLP and CAPS markers for marker assisted selection for fungi - disease resistance plant can trim down the infection [78, 79].

Conclusion

Brassicaceae being valuable for oil, edible purposes and meal composition faces a huge yield loss due to fungal diseases. However, considering epidemiological circumstances disease control can be done for temporary period, but in order to have more effective control on fungal pathogens an additional research is needed to optimize and combine the traditional method of disease control and genetic manipulations by combining different useful traits from distant species for development of better germplasm; so as to prepare disease resistant, stable, high yielding, environment friendly and functional food along with nutritional properties. Above review provides a thorough account of the fungal diseases and the associated pathogens indulged in significant yield loss of Brassicas along with the preventive measures to deal with the disease causing pathogens. To conclude this review, we suggest that Brassicaceae family owe significant space in studies relevant to fungal disease resistance.

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