

Review Article

Epidemiology and management practices of fungal and bacterial diseases of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

ABSTRACT

Economic significance of pearl millet has recently received more attention than ever, especially in light of the great nutritional value of gluten-free diets for ~~celiac disease sufferers~~ people with celiac disease. The most major diseases ~~that afflict pearl millet include smut, ergot, rust, leaf blast, and green ear disease/downy mildew, despite the fact that many new varieties have been afflicted~~ pearl millet include smut, ergot, rust, leaf blast, and green ear disease/downy mildew, despite many new varieties being created throughout the years. ~~Yet~~ Nevertheless, in order to effectively control them and maximize the crop's economic production, ~~diseases~~ like leaf blast, rust, smut, bacterial leaf spot, stripe, and strike also require early attention. ~~Result,~~ thorough-comprehensive data has been gathered in this review within the categories of aetiology, epidemiology, and management practices. The goal of this review is ~~known the status of pearl millet diseases are~~ to know the status of pearl millet diseases is properly-adequately understood, and their correct present management approaches and the need for future prospects is underlined.

Key words: Pearl millet, Fungal diseases, Bacterial diseases, Epidemiology, Management

1. INTRODUCTION

Pearl millet ~~continues to be the main food and economic source for millions of people in the third world nations~~ remains the main food and economic source for millions of people in the third world. Consumption of "fura," or large balls made of flour, parboiled grains, or fermented drinks, is widespread [1]. India contributes 44% of the world's total millet production to the production of pearl millet. Pearl millet crop is viewed as a species with high ~~levels of hardiness due to its~~ great hardiness ~~hardiness levels due to it~~ excellent drought resilience and low needs for soil fertility [2]. For rural residents in the drier parts of the country, it is their ~~main primary source of dietary energy~~ dietary energy source. From the vantage points of production, consumption, and trade, it is notable that the Ministry of Agriculture and Farmers Welfare of the Government of India has categorized it as "Nutri-Cereals" [3]. It is a plentiful source of many ~~nutrients that are good for you~~ good nutrients, including iron, zinc, folic acid, beta-carotene, and protein. The grain can be used to combat malnutrition brought on by a deficiency in minerals since it has a moderately high content of the vitamins thiamine, riboflavin, and niacin [4, 5]. In addition to being rich in nutrients, it provides a cheap alternative for addressing micronutrient shortages in areas where millet is consumed and has the

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potential to be used ~~in the production of to produce~~ recipes that are very rich in nutrients [6, 7, 8]. It is also utilized for a sizable number of non-food uses, including ~~as the production of producing~~ alcohol, animal feed, poultry, and cow feed, and feed for other species [6, 9]. Pearl millet generally contains more protein and fat than sorghum, and its energy content is highest among ~~whole grain~~ grains. Bajra is a top cereal for fiber content as well [10].

Unfortunately, the crop suffers substantial losses as a result of ~~a number of several~~ biotic factors. The most major productivity constraints imposed by biotic factors on ~~the production of producing~~ pearl millet are diseases caused by fungi, bacteria, and viruses. ~~A large number of Many~~ diseases have been noted in areas where pearl millet is extensively grown. A brief review ~~on of~~ the status of fungal and bacterial diseases of pearl millet has been least with here.

2. Fungal Diseases

2.1 Downy mildew

One of the main biotic yield-reducing factors is ~~the~~ downy mildew of pearl millet, which is caused by *Sclerosporagrammicola* (Sacc.) Schroter. This is the most significant disease of pearl millet in ~~the~~ worldwide [11]. The most significant ailment affecting pearl millet is downy mildew, ~~which is brought on by the fungus Sclerospora graminicola in both brought on by the fungus Sclerosporagrammicola in~~ Asia and Africa [12, 13, 14, 15]. In Asian nations like India, ergot is this crop's second-most dangerous disease [16, 17]. ~~Its output is negatively impacted by other serious fungal diseases Other serious fungal diseases negatively impact its output other serious fungal diseases negatively impact its output~~ as rust, blast, and smut, as well as bacterial and viral infections [18, 19, 17].

2.1.1 Epidemiology

The two distinct types of symptoms that are brought on by the diseases are downy mildew and green ears. Downy mildew symptoms can appear on the first leaf, although they typically appear on the second and third leaves. Chlorosis of the leaf lamina, which appears as these signs, travels from the infected leaf's base upward. As the plant grows, the chlorosis spreads to the higher leaves ~~and eventually covers~~ the entire lamina on the third or fourth leaf. The abaxial surface of the leaves develops abundant asexual sporulation when the relative humidity is over 95%, and the temperature is moderate, giving the leaves a downy appearance. Plants that have been severely harmed continue to develop slowly and don't produce panicles. Half-leaf symptoms, which have a distinct border between the diseased (basal) region and the non-diseased parts at the tip of the leaf, ~~are what~~ define the disorder. Because the disease has systemic disease manifestations, if symptoms occur on one leaf, they will also appear on all succeeding leaves and the panicle [20, 21].

The signs of ~~the~~ green ear appear on panicles and are caused by ~~the transformation of transforming~~ floral elements into leafy structures. The oospore, which has thick walls, a black-walled exosporium, and an adherent oogonial membrane, gave rise to the name "*Sclerospora*" [22, 23].

Oospore germination is thought to occur best at a temperature of 28.2°C. The significance of oospores in the study of disease epidemiology is demonstrated by the significant association between the density of oospores in the soil and the occurrence of disease [24]. The oospores play a vital part in the disease's propagation, just as the spores transferred by seeds are essential to ~~the development of developing~~ downy mildew [25, 26]. Oospores, ~~which are~~ naturally present in ~~the~~ soil, are the ~~main primary~~ source of inoculums and usually infect plants' underground areas when they are in the seedling stage [27].

2.1.2 Management practices

It is vital to sterilize moist soil for more than two hours ~~in order to ensure the complete removal of all oospores in the soil because the diseases is to ensure the complete removal of all oospores in the soil because the diseases are~~ spread via oospores found in soil and seed. Oospores can be killed more effectively by steam sterilization [28]. ~~A p~~Pre-sowing seed treatment is preferable to fungicide treatment with Thiram and Captan. Metalaxyl has been found to have extremely powerful *in vitro* and *in vivo* activity [29]. Downy mildew disease is effectively controlled by other strobilurin fungicides and oomycetocides [30, 31, 32]. Pearl millet seeds were treated with BABA (Beta amino butyric acid), which increased seedling vigour, protected them from downy mildew, and revealed a 23% increase in disease incidence ~~when~~ compared to the control [33]. Raw cow's milk and *Gliocladium virens* seed and soil treatments have been recommended as natural control options. *G. virens* controls downy mildew [20]. To increase disease control and seedling vigour, some researchers advise combining biopolymers with fungicide/oomycetocide and using them as seed treatments. In this regard, biopolymers from various plants, including *Acacia arabica*, neem, drumstick, papaya, atrocarpus, and mimosops, have been researched and recommended for use in treating pearl millet seeds along with a half-dose of Metalaxyl, which is very effective in preventing pearl millet downy mildew [34]. *Artemisia pallens*, *Helianthus annuus*, *Murrayakoenigii*, *Tagetes erecta*, *Citrus sinensis*, *Thuja occidentalis*, *Ocimum basilicum*, *Agave americana*, *Parthenium hysterophorus*, *Dalbergia latifolia*, ~~and~~ *Zingiber officinale* are other plants with methanolic extracts that have antispore activity against *S. graminicola* [35].

In view of the emergence of metalaxyl resistance, a search for substitute systemic fungicides is currently under progress. Researchers came to the conclusion that acylanilide-series fungicides are the best at preventing downy mildew as a result of the findings. Yet a cost-benefit analysis reveals they are not worthwhile [35, 32]. Therefore, the most recent and effective way to prevent the spread of this deadly pathogen is to cultivate ~~disease-resistant varieties include-resistant varieties including~~ PHB 10, WCC 75, ICMH 451, Mallikarjuna, ICTP 8203, HB 5, HB-1, and PHB 14. Sometimes, resistance is created in pearl millet by menadione sodium bisulfite treatment of the seeds, which causes the crop's protective enzymes to be amplified before seeding [36]. The use of antagonists has grown over the past few decades because chemical therapies are ~~nor environment friendly and either environment friendly nor~~ short-lived. *Trichoderma hamatum* treatment of seeds resulted in significantly increased germination rates and stronger ~~seedlings for pearl millet as well pearl millet seedlings~~ [37]. *Bacillus* spp. ~~treatment~~ Treatment of seeds has also ~~been~~ demonstrated to be ~~an effective practical~~ preventative

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approach [38]. Treatment with chitosan nanoparticles (CN), made from low molecular weight chitosan, can make pearl millet resistant to *Sclerosporagraminicola* [39].

2.2 Ergot

Ergot is a fungus called *Claviceps fusiformis* Lov. Even high-yielding hybrids ~~have shown to be~~ particularly vulnerable to declining due to this disease. Losses of between 58 and up to 75% in terms of grain, seed production, seed quality, germination, and seedling emergence have been reported [40]. When an ergot-infected grain is consumed, it can poison pearl millet's consumers, including people, birds, chicks, and animals. Affected organisms exhibit symptoms such as nausea, vomiting, dizziness, and tiredness [41, 21].

2.2.1 Epidemiology

Between September and October, which are rainy season months, the disease first appears in the host's inflorescence. Between the glumes of the damaged ear head tissue, sticky, sugary exudates that resemble honeydew are visible. The first indication of infection appears after 8 to 10 days after flowering. A severe infection would ~~result in the entire ear head becoming dark to black and becoming~~ make the entire ear head dark to black and mushy and sticky. Honeydew would also flow on the leaves, ~~which would include~~ including a lot of many conidia, which are asexual spores. Dark brown to black sclerotia develop during ~~a period of~~ roughly 14–20 days following the appearance of honeydew. Instead of grains, these sclerotia can be seen sticking out from the florets [12, 41].

The disease is disseminated via sclerotia-infected seeds, as well as by soil- and airborne conidial inoculums. Insects that spread the sclerotia inoculum are another factor in the disease's enduring nature. Mature sclerotia may contaminate the grain or fall to the ground during harvest and threshing. These sclerotia serve as the disease's main inoculum in the ~~crop of the following year~~ following year's crop [11].

The ascospores that are produced when the sclerotia germinate might lead to infection in otherwise healthy ear-heads of pearl millet. ~~It has been found that the sclerotia in semi-arid regions~~ The sclerotia in semi-arid regions have been found to release asexual spores, commonly known as conidia, after germination. Insects, wind, and raindrops distribute these conidia over the area [42, 11].

2.2.2 Management practices

The ergot disease is difficult to manage and control. In addition to ~~the development of disease-resistant lines, a number of~~ developing disease-resistant lines, several other management strategies using cultural, chemical, and biological interventions have been documented. Plowing the field deeply during the warm summer months is indicated ~~for the purpose of lowering~~ to lower the main inoculum load of the pathogen. This practice buries the sclerotia to the depth that their germination is prevented. The primary inoculum can be cut down by using seed that is derived from ~~crops that were disease-free~~ disease-free crops. Hybrids with the characteristics of quick pollination have been shown

to be an effective bio-cultural control measure against the disease [41]. Spraying the ear-head with fungicides like Cuman-L (200 ppm), Ziram (0.1-0.15%), and Aureofungin has been tried by a number of several researchers, with varying degrees of success. 8-hydroxyquinoline has been proven to be 90% effective in controlling the disease.

2.3 Smut

Tolyposporium penicillariae syn. *Moesziomyces penicillariae* is a fungus that causes smut disease, which mostly affects the plant's flowers. Five to thirty percent of harvest loss is attributed to this disease [43, 15]. Senegal was the first country to report the disease, followed by India [15].

2.3.1 Epidemiology

The ovaries in the inflorescence of infected flowers transform into a black powdery mass (sori), signaling the onset of pearl millet smut. The projecting sori between the glumes of a typical grain are often larger and more significant than the seed they surround, measuring 3–4 mm in length and 2–3 mm in width. Initially, sori is present as a glossy green, but as it ripens, it changes color, moving from green to brown to black. The seed is supplanted by tiny, dark spores. At maturity, the slimy coating on the sorus bursts and releases the spores within. When mature, spores released into the air cause disease in otherwise healthy panicles [44, 41].

The spore balls are dense, spherical clusters of teleutospores and range in shape from angular to circular, are brown in colour, and are 7-12 m in diameter. There is no way to isolate individual teleutospores. Germination of a teleutospore is promoted at a temperature of 30 degrees Celsius. Upon germination, teliospores produce a four-celled promycelium that produces lateral and terminal sporidia. Variable teleutospore development and chainlike sporidia formation on branching hyphae characterize spore balls [41]. In the field, the teleutospore (resting spores) of the pathogen and infected seeds or soil is the principal source of inoculum. Airborne sporidia are responsible for primary infection, which occurs when badly contaminated grains are utilized for planting. To create a dense mycelial network, spores germinate when conditions are right. During the blooming stage, teleutospores from promycelia and sporidia germinate and infect the floral organs [44]. After sporidia have landed on the ovaries, it takes 14 days to develop the spore and another 21-28 days for the sori to mature [45].

2.3.2 Management practices

In order to avoid the germination of fungal spores, thorough ploughing must be performed after the spores have been buried deeply in the soil. Intercropping pearl millet with other crops, such as mung bean, is another method that helps reduce the risk of infection. The disease may be efficiently managed in the field with just four sprays of Capatafol, Thiram, or Captan at a concentration of 3mg/L. [46] have reported in-vitro evaluation of fungicides against smut pathogen and found thiram providing relatively best inhibition of diametric growth of *T. penicillariae*.

Compared to the field's control, a soil treatment with *Gliocladium virens* and raw goat milk and cow milk treated seeds provide up to 60% better protection [47]. It is regarded as a key element of a comprehensive plan for smut control for farmers with insufficient access to resources. Resistance cultivars [have recently been created and advised, including DC 7, MPP 7131, and MPP 7108](#) including DC 7, MPP 7131, and MPP 7108 have recently been created and advised.

2.4 Rust

Rust of pearl millet appears in [the](#) later stage of crop growth, mainly during [the](#) seed developing stage, commonly occurring after [the](#) grain-filling stage, producing [a](#) minor reduction in grain production. Rust of pearl millet emerges in [the](#) later stage of crop growth. *Puccinia penniseti* Zimm. ~~The pathogen that causes this disease is the pathogen that leads to this disease.~~ This disease manifests ~~itself on the leaf as a reddish-orange pustule that can range in shape on the leaf as reddish-orange pustule that can range~~ from circular to oval. The pustules initially appear on the distal half of the leaf, and later they extend over both sides of the leaf. The pustules that have matured burst, releasing rusty spores in the process. There is a possibility that the symptoms will occur not only on the stem but also on other plant sections. Plants with severe rust damage have a rusty, brownish-red appearance [41].

2.4.1 Epidemiology

On pearl millet crops, the first signs of the disease manifest as uredinia pustules that are round and range in color from reddish brown to ~~reddish-reddish~~-orange. The infected leaf eventually dies, starting at the ~~very tip and working its way~~ tip and working down. It generates teliospores and uredospores on [the](#) crop, [the](#) same as other species of *Puccinia*, and furthermore, on alternate hosts such as *Solanum melongena*, it yields aecial spores [44]. On pearl millet crop *P. substriata* var. *indica* and *Puccinia substriata* var. *penicillariae* generates basidial, uredinial, and telial phases because to its macrocyclic structure. In the latter phases, telia take the role of uredinia and become sub-epidermal, black, and ovoid. The pustules produce a cluster of spores known as urediniospores. These spores are responsible for the spread of ~~the~~ rust disease throughout the crops. After ~~a period of some~~ time, pustules darken in color and ~~take on the appearance of another~~ appear as a type of spore called a teliospore. The leaves become wilted starting at the top and the way down. If the disease incidence is particularly high, additional rust pustules may emerge on the stems, ~~which may ultimately result in the death of the plants ultimately resulting in the plants' death.~~ The teliospore has a number of tough exterior layers, which allow it to survive for an extended amount of time in the soil. ~~To~~ [The](#) complete its life cycle, the fungus must first go through the spermatogonial and aecial stages on another host, such as solanum [41].

2.4.2 Management practices

Chemical treatment involves ~~use of~~ Propiconazole, Hexaconazole, Copper oxychloride, Carbendazim, Mancozeb, Azadirachtin [48, 49]. At [the](#) initial stages, spray with ~~any of the~~ fungicides like Wettable sulphur ~~sulfur~~ or Mancozeb is recommended. The ~~antibiotic~~

fungicide Triadimefon has also performed satisfactorily against pearl millet rust under field conditions and recorded the least-most minor rust severity. Also, rust of pearl millet can be managed to a great extent with *Trichoderma viride* [50] and *T. harzianum* [51] spray and is significantly superior in comparison greatly with *Trichoderma viride* [50] and *T. harzianum* [51] spray and is significantly superior to other chemical treatment methods.

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Also, cultural practices like adjusting the sowing date so that the crop does not flower during September when high rainfall and high relative humidity favour the disease spread are also useful/helpful. For eradication of To eradicate collateral hosts, the seeds are immersed in the common salt solution, and the floating sclerotia are removed. Furthermore, growing resistant varieties like PHB 10, 14; Co 2, 3, and Bajra are practiced.

2.5 Helminthosporium leaf spot

Helminthosporium bipolaris setariae causes this disease. Little, brown spots or oval to oblong or rectangular patches on leaves are the symptoms of the disease. Lesions may grow and clump together. Lesions typically have a more or less noticeable dark brown border and are tan or greyish greyish-brown in color. Seedling blight and significant loss could result from an early infection. The collateral hosts, stray crops, crop leftovers, and possibly some seed-borne hosts are how this pathogen perpetuate/perpetuate. Conidia carried by the air may aid in the secondary transmission of the diseases [41, 7].

2.5.1 Epidemiology

Many ovals to oblong leaf spots that are brown or have a grey core with brown edges are among the severe-tough leaf spot's field symptoms. Leaf spots on older leaves are characterized by many, consolidated spots that caused tip-burn and withering. Before the seed ripened, the majority of the most plants perished [52].

2.5.2 Management technique

Practices including deep ploughing, clearing, and removing crop remains from the field, cleaning the infected plants from the field, and burning crop residues are advised for the treatment of to treat this disease [21].

2.6 Cercospora leaf spot

This illness is brought on by the fungus *Cercospora penniseti*, and it typically has a little economic impact.

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2.6.1 Epidemiology

Pearl millet may have circular lesions with dark brown edges and pale tan to grey or white cores that are dotted with rows of black conidiophores as the symptoms of leaf spots. Stems can also develop lesions. Thus, it has little economic significance. This pathogen survives on ~~of~~-crop debris, stray plants, side hosts, and seed. Airborne spores may cause secondary spread[41, 7].

2.6.2 Management technique

Practices including deep ploughing, clearing field bunds after the crop season is finished, removing crop remains from the field, uprooting the infected plants from the field, and burning crop residues are advised ~~for the treatment of~~ to treat this disease [11].

3. BACTERIAL DISEASES

3.1 Bacterial leaf spot

The bacterium that causes bacterial leaf spots is *Pseudomonas syringae*[53]. ~~It's possible that a plant's entire leaf canopy will~~ A plant's entire leaf canopy may sustain damage. Although the pathogen primarily affects the leaves, the stem might ~~occasionally show streaks as well~~ also show streaks. This bacterium is soil-dwelling and survives by consuming crop residue. When rains strike surfaces and facilitate the movement of bacterial cells to new infection sites, the disease travels to new locations [11].

3.1.1 Epidemiology

The first signs of bacterial spots on leaves are ~~small~~ minor, elliptical, or irregularly shaped spots with a straw-colored centre and a black ring. These spots gradually unite to form huge bands. The patches initially have a light, ~~yellowish-yellowish~~-brown appearance, but very quickly, they darken to a considerably darker brown. After the disease has progressed to a more severe level, the leaf has split along the stripe. Every leaf of a plant may sustain damage. The predominant ~~site of attack for this disease is the leaves, while it~~ attack site for this disease is the leaves, which can also occasionally ~~show up~~ appear on the peduncle. This bacterium pathogen survives on crop residue in the soil. When rain splashes onto surfaces, the disease is spread secondarily because the bacterial cells are more easily transported to new infection sites. A wet, chilly atmosphere ~~with a temperature~~ between ~~12° 12°~~ and ~~25° 25°~~ degrees Celsius is necessary for ~~illness~~ disease to thrive [21].

3.1.2 Management technique

Deep ploughing in the summer, clearing, removing crop bundles, disease plants, and crop residues from the field, burning crop residues, and controlling irrigation water from entering neighboring fields are all examples of field maintenance. In addition to the practices mentioned above, prompt removal of volunteer weeds, wild crop species, collateral, and alternate hosts can help ~~in its~~

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~~control-control~~ diseases like ergot because they serve as reservoirs for pathogens and sources of inoculums [11].

3.2 Leaf bacterial stripe

The pathogen responsible for bacterial leaf stripe is *Pseudomonas avenae*. It also goes by the name "bacterium *Acidovoraxavenae* subsp. *avenae*" and has been reported seed-borne in graminaceous species [54, 55, 56]. It was first identified in 1909 as the cause of oats' (*Avenae sativa* L.) leaf blight, a disease that affects many species when there is a lot of rainfall and heat [57, 58, 59, 60].

3.2.1 Epidemiology

The formation of the stripes with a water-soaked, reddish-brown look may be seen on the pearl millet growing leaves [61]. ~~Almost always, the lamina's damaged area seems to be~~ The lamina's damaged area almost always seems straw in color. Occasionally, it will even get to the leaf's tip. Hydathodes are also thought to act as the bacterium's point of entry of the pathogen. Although the stripes occasionally reach to the leaf's border, they always leave the midrib and centre of the leaf unaffected [62]. ~~Throughout the length of the affected culms and leaf sheath, a light brown color darkening can be visible~~ A light brown color darkening can be visible throughout the length of the affected culms and leaf sheath. Frequently, the discoloration begins 5 to 7 cm above the base and extends all the way ~~The discoloration frequently begins 5 to 7 cm above the base and extends~~ to the leaf sheath. ~~It is believed that this pathogen spreads~~ This pathogen is believed to spread internally between plants in latently infected plants and through farm equipment in rice [54, 63]. ~~If there are agricultural waste products~~ agricultural waste products are in the soil, the pathogen can survive there. Since they make it simpler for bacterial cells to reach new infection sites, rain splashes may be to blame for the secondary spread of disease [57, 63].

3.2.2 Management techniques

Both cultural and chemical strategies are used to control the disease. The primary inoculums load of the pathogen is reduced as part of cultural control. It is advised that fields be deeply tilled in the warm summer months to bury the sclerotia as deeply as possible to prevent the sclerotia from sprouting. Using seeds s from disease-free crops will reduce the amount of the initial inoculum. A successful bio-cultural control strategy against the illness has been demonstrated by hybrids with rapid pollination traits [64].

3.3 Leaf streak

Caused by the bacterium *Xanthomonasaxonopodis* sp. *pennamericanu*.

3.3.1 Epidemiology

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Thin, water-soaked, transparent leaf stripes that are 2-3 mm wide and 2-15 mm long are the disease's first visible symptoms. ~~As early as the seedling's second leaf stage, these stripes might appear~~These stripes might appear as early as the seedling's second leaf stage. The lesions become opaque with red rims with oval patches. Moreover, these lesions may enlarge into ~~bigger~~more prominent regions. In more extreme cases, these lesions may unite to form extensive, uneven streaks and blotches that cover the majority or the entire leaf blade. If ~~there are agricultural waste products~~agricultural waste products are in the soil, the pathogen can survive there. ~~In temperatures between 26° and 30° C, this disease is most prone to spread~~This disease is most prone to spread in temperatures between 260 and 300 C. When temperatures are low in the spring, the disease manifests more severely, ~~and w. It manifests less severely when it's hot and dry in the summer~~when it's hot and dry in the summer, it manifests less severely[11].

3.3.2 Management techniques

The primary inoculum can be reduced by using seeds that came from disease-free crops. Quick pollination hybrids have proven to be an efficient biocultural control strategy against the ~~illness~~disease[64].

4. CONCLUSION

The need for more food has increased with the population, but the demand for pearl millet is predicted to drop as the crop's output is severely constrained ~~by bacterial, fungal, and other unanticipated diseases~~. This risk might be reduced if yield stability could also be increased by including drought, insect, and disease resistance or tolerance. The current assessment underscores that because farmers find it difficult to treat broad areas with pesticides, the chemical control is neither economical and environment friendly ~~nor~~ practical to the farmer. As a result, the development of biological and environmentally friendly control measures is urgently needed.

~~Concern~~The concern is also expressed over the impact of host-associated microbial communities, the impact of climate change, the incidence and prevalence of disease symptoms, and crop losses. Furthermore, this review ~~emphasises~~ the need for more significant and focused studies to comprehend the progression of the less well-studied bacterial diseases, their pathogenicity, and disease management in light of the unpredictability of climate change and the emergence of new pathogens like stem rot of pearl millet (*Klebsiella aerogenes*). More thorough research is required to be ready for any forthcoming future disasters.

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Comment [CdM4]: updated references

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