A Comprehensive Review on Major Diseases of Strawberry with Integrated Management

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Abstract
Strawberry is one of the most economically important and widely cultivated small fruit crops worldwide, valued for its attractive appearance, pleasant flavor and high nutritional content. In Bangladesh and other subtropical regions, favorable winter agro-climatic conditions and increasing consumer demand have accelerated the expansion of strawberry cultivation as a high-value crop, contributing to income diversificationand employment generation. However,sustainableproductionis seriously constrained by a wide range of diseases caused by fungal, bacterial and soil-borne pathogens, often compounded by insect pests. Major diseases such as root and crown rots, anthracnose, gray mold, powdery mildew, fungal and bacterial leaf spots consistently cause significant yield losses and deterioration of fruit quality. Conventional reliance on calendar-based chemical control has provided limited success and raised concerns related to fungicide resistance, environmental pollution, residue hazards and escalating productioncosts.Thisreviewcomprehensively synthesizes existing literature on the prevalence, symptoms and etiology of major strawberry diseases and critically evaluates their management options with emphasis on integrated disease management (IDM). The review highlights the effectiveness of combining disease-free planting materials, crop rotation, improved soil and canopy management, sanitation, biological control agents, botanicals and judicious use of fungicides within an integrated framework. By consolidating fragmented research findings and identifying key knowledge gaps,particularly in subtropical production systems, this review aims to support researchers,extensionpersonnelandpolicymakers in developing environmentally sound,economically viable and sustainable strategies for disease-free strawberry production.

Keywords:
Integrated disease management (IDM); Root and crown rot; Anthracnose; Gray mold; Powdery mildew; Leaf spot; Integrated pest management (IPM); Sustainable strawberry production.

Introduction

Strawberry ranks among the most widely cultivated and economically significant small fruits worldwide, appreciated for its visual appeal, desirable taste and rich nutritional profile, including vitamins, mineralsand health-promoting antioxidants [1]. In many countries, Bangladesh included, rising consumer preference and favorable winter agro-climatic conditions have stimulated rapid growth of strawberry cultivation as a high-value enterprise, creating opportunities for farm income diversification and employment generation [2-3]. However, this expanding production is severely challenged by numerous diseases caused by fungal, bacterial, viral and nematode pathogens, which collectively impair plant health,

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reduce yield and compromise fruit quality, often making intensive cultivation economically unviable [4-5]. Among the reported constraints, Botrytis grey mould, anthracnose fruit and crown rot, powdery mildew, leaf spot and scorch complexes, along with soil-borne root and crown rots, are consistently identified as the most destructive diseases across major strawberry-growing regions, including South Asia [6-7]. Traditionally, disease control has depended largely on frequent, calendar-based fungicide applications. Although such practices may offer temporary relief, they have contributed to the development of fungicide resistance, escalating production costs and increasing concerns over chemical residues and environmental safety [8-10]. In Bangladesh and other subtropical regions, these problems are further intensified by the widespread use of susceptible cultivars, limited understanding of local pathogen diversity, poor availability of disease-free planting materials and inadequate crop management practices, making disease pressure a critical obstacle to sustainable strawberry expansion [11-12]. Consequently, integrated disease management (IDM) has gained prominence as a holistic and sustainable approach, integrating healthy planting materials, resistant or tolerant varieties, crop rotation, improved soil and canopy management, sanitation measures, biological control agents, botanicals and judicious fungicide use [13-14]. Research evidence demonstrates that such integrated strategies can substantially reduce disease incidence and severity while enhancing yield and fruit quality; however, relevant findings remain fragmented across different regions, pathogens and management practices [15-16]. Against this background, the present review synthesizes existing knowledge on the prevalence and distribution of major strawberry diseases, clarifies critical aspects of their pathogenesis and host–pathogen interactions and critically assesses current and emerging IDM options, with particular emphasis on subtropical production systems. By consolidating dispersed research, identifying knowledge gaps and outlining future research needs, this review aims to assist researchers, extension workers and policymakers in developing resilient, economically feasible and environmentally sustainable disease management strategies, underscoring the necessity of adopting integrated disease management for the production of disease-free strawberries.

Diseases of strawberry and control

Strawberry plants are susceptible to numerous diseases, which differ greatly in their severity and geographic distribution. Effective disease prevention starts with planting healthy, disease-free stock, preferably with genetic resistance, and following recommended cultural management practices. Additionally, ensuring the production of disease-free plants and fruits may necessitate the preventive use of fungicides [17].

Root rots

Many root-rotting diseases in strawberries can be largely prevented through annual planting, provided that effective cultural practices are implemented. Crop rotation is a key strategy for reducing root-related diseases (Fig. 1). Strawberries should not be planted in fields that previously grew strawberries or other solanaceous crops for at least five years, with a ten-year rotation period being even more desirable. Planting should be limited to well-drained soils, although raised beds can improve conditions in marginal areas. In soilless production systems, particularly those containing low amounts of peat moss or other organic composts, the risk and severity of black root rot pathogens, especially *Pythium* species, are significantly higher than in soil-based systems. The application of *Trichoderma* has proven effective in managing these pathogens, which can otherwise cause severe root damage and plant collapse in susceptible strawberry varieties [18].

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Fig.1. Plant with Root Rot.

Control

Pre-plant soil fumigation is the primary method for controlling these root diseases. Additionally, selecting sites with well-drained soils, maintaining overall plant health, and preventing stresses such as water deficiency, winter damage, and herbicide injury are important cultural practices that help reduce disease incidence [19].

Anthracnose

Several species of fungi that are closely related can cause a variety of symptoms including fruit rot, crown rot, leaf spots or lesions on runners and petioles. Most commonly observed and problematic for strawberry plants is anthracnose fruit rot, which first appears as tan sunken fruit lesions on the fruit that then turn dark brown or black in color (Fig.2). Salmon-colored spores also may eventually appear on these lesions. At this time, no ever bearer cultivars have been noted to have resistance, though degree of susceptibility varies. This disease is a warm weather disease; thus, fungicides are not needed until temperatures warm, usually about the time that the first fruit are formed [18].

Fig.2. Strawberry Fruit with Anthracnose.

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Control

Cultural practices play a vital role in managing anthracnose and should focus on obtaining disease-free planting material from a reliable supplier and avoiding highly susceptible cultivars. In addition to these preventive measures, several fungicides are available that effectively control anthracnose, although many belong to the strobilurin chemical class and should be used carefully to manage resistance risk [19].

Gray mold

Gray mold, characterized by a gray, fuzzy coating on infected fruit during spore production, is caused by the fungus *Botrytis cinerea*. This pathogen survives both as a parasite on living tissues and as a saprophyte on decaying plant debris. It commonly invades developing fruits, remaining latent until ripening, at which point it causes rapid fruit rot. The fungus can also lead to blossom blight, particularly during extended periods of cool, wet, and overcast weather, and may cause browning of the fruit caps. Effective protection begins with fungicide applications during the bloom period, as the fungus initially infects the blossoms and grows into the tissues that will later form fruit, with symptoms appearing only at maturity. Mature fruits can also become infected through contact with diseased fruit or leaves, especially when in direct contact with already infected material. Cultural practices that promote rapid drying of foliage and fruit, such as maintaining weed-free fields and keeping row middles short, help reduce leaf wetness duration, which is essential for fungal spore germination and infection [18].

Control

Managing gray mold can be aided by cultural practices that reduce sources of inoculum.Theseincludefrequentharvesting, prompt removal of rotting or overripe fruit, and clearing dead or senescent foliage from the field. In addition, several fungicides are effective against gray mold, but those chosen should have a short pre-harvest interval to ensure fruit safety. Fungicide applications must follow label instructions and may need to be repeated because of the extended flowering and fruiting period of strawberries [19].

Powdery mildew

Powdery mildew in strawberries is caused by the fungus *Sphaerotheca macularis*, which requires living plant tissue to survive. Infection produces a white, powdery coating on the upper surface of leaves, while the underside may develop a purplish discoloration that can cause the leaves to curl inward. Fruits affected by this disease also show a white, powdery layer, and the seeds may detach easily when the fruit surface is rubbed (Fig.3).

Fig.3. Powdery Mildew on Fruit.

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Although relatively rare, the fungus can also infect flower parts, which may result in fruits failing to develop or becoming severely deformed. Powdery mildew tends to worsen under conditions of warm temperatures, high humidity, and low rainfall. Consequently, the disease is often more prevalent in high tunnel systems than in open-field cultivation [18].

Control

Cultural control of powdery mildew involves practices that reduce humidity within the planting, such as maintaining weed-free fields and ensuring proper ventilation in high tunnels. While several fungicides are effective against the disease, there is a risk of resistance development. To prevent this, fungicides should be rotated among different chemical classes, and the number of applications should be kept to a minimum whenever possible [19].

Fungal leaf spots

Several types of leaf spot diseases can affect strawberries, particularly later in the season when foliage growth slows and cool, damp conditions favor fungal spore production. The three most common leaf spots can be distinguished by their appearance. Common leaf spot typically produces small lesions, about 0.12–0.25 inches in diameter, often with a white center that may fall out as the spot matures. Leaf scorch appears as dark red to purple, solid-colored spots that can merge, covering large portions of the leaf and causing tissue death. Leaf blight usually starts as a V-shaped discolored wedge, widest at the leaf margin, and is generally less problematic within a planting (Fig.4). These diseases can also infect fruit caps, reducing the visual quality and marketability of the fruit [18].

Fig.4. Common Leaf Spot

Control

Cultural practices that help reduce leaf wetness and lower humidity in the planting can effectively limit leaf spot development. In addition, several fungicides are registered and can be used to manage the different types of leaf spot diseases in strawberries [19].

Bacterial leaf spot

This disease tends to be more severe under cool, wet conditions, such as during spring when overhead irrigation is used for frost protection or in the fall as temperatures drop. Bacterial leaf spots can be distinguished from fungal leaf spots because the affected areas appear translucent when held up to light, giving a “windowpane” effect between the small leaf veins. Initially, the spots are confined by these veins, resulting in an angular shape, unlike the circular lesions seen in common leaf spot and leaf scorch (Fig.5 and Fig.6). When the fruit caps remain wet, they develop a blackened appearance, which turns brown as they dry. All ever bearing cultivars tested in the eastern regions show moderate to high susceptibility to this disease [18]

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Because this disease is caused by bacteria rather than fungi, conventional fungicides are ineffective. However, applications of copper-based sprays can help in managing the infection. [19]

Fig.5. Common Leaf Spot on the Calyx.

Fig.6. Leaf Spot with Light from Black.

Common insects and its control

Insects are a frequent challenge in strawberry cultivation, affecting plant health and fruit quality. Strawberries are commonly attacked by pests such as Japanese beetles, aphids, thrips, weevils, nematodes, and mites. Some of the key insect pests found in strawberry fields are listed below.

Tarnished plant bug

The adult tarnished plant bug is a small insect, about 0.25 inches long, with a brownish "brassy" appearance and a distinct V-shaped marking on its back just behind the head. This true bug has piercing-sucking mouthparts and feeds on a variety of weeds and cultivated crops. Multiple generations occur each year, with adults and nymphs present from April until the first frost in fall (Fig.7 and Fig.8). Because several generations develop in a single season, populations tend to increase as the season progresses, making damage to ever bearing cultivars often more severe than in June-bearers. Tarnished plant bug adults overwinter in protected areas and return to strawberry fields in the spring, feeding on various plant parts. The most noticeable damage occurs when they feed on the seeds and fruit tissue of developing berries [18].

Fig.7. Late Instars Tarnished Plant Bug

Fig.8. Adult Tarnished Plant Bug

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Control

Controlling tarnished plant bugs in Everbearing strawberries can be challenging because of the extended flowering period.

Additionally, mowing nearby weedy areas or hayfields can exacerbate the problem, as displaced plant bugs often move into adjacent strawberry fields [19].

Potato Leafhopper

The potato leafhopper does not survive the winter in the Northeast; instead, it is carried into the region each year by winds from the South. These pests typically become more problematic in early to mid-summer and often infest strawberry fields following the harvest of nearby hay fields. Low populations can be difficult to detect because the adults are very small, about 0.12 inches long, and quickly disperse when disturbed (Fig.9). The light green nymphs, however, remain on the undersides of leaves and move sideways to avoid detection. As populations grow, affected leaves exhibit downward cupping and yellowing, with symptoms usually most severe on small or stressed plants [18].

Fig.9. Potato Leafhopper.

Control

Potato leafhopper populations need to be managed when they reach levels that cause damage, as unchecked infestations can stunt plant growth and reduce late-season fruit production. Although several insecticides are registered for use on strawberries, cultural controls are generally ineffective because the insects migrate into the region from outside sources [19].

Strawberry sap beetle

Adult sap beetles are small, dark brown, oval-shaped insects, approximately 0.12 inches long (Fig.10). They feed by chewing small holes in ripe fruits, often targeting areas in contact with the ground. In addition to the visible feeding damage, which can resemble that caused by slugs, sap beetles also introduce fruit rot pathogens as they feed. These beetles can be difficult to detect unless populations are high, as they quickly drop to the ground and seek shelter when disturbed [18].

Fig.10. Sap Beetle.

Control

The most effective way to manage sap beetle populations is through cultural practices. Since these beetles are strongly attracted to decaying fruit, maintaining good field sanitation is crucial. Growers should harvest berries before they become overripe and promptly remove or destroy any unmarketable fruit rather than leaving it in the field. It is also recommended to avoid planting more strawberries than can be harvested in a timely manner. While pesticides can be used, they are generally less effective than proper cultural management in controlling sap beetle populations [19].

Slugs

Slugs are mollusks that can inflict significant damage on strawberries by creating small, moderately deep holes in ripening fruit. They often feed beneath the fruit caps, although feeding damage can occur anywhere on the berry. Typically nocturnal, slugs may also feed during overcast or rainy daytime conditions. The presence of shiny slime trails on the plants or ground is a clear indicator of their activity [18].

Control

Slug populations can be managed using several approaches, but habitat modification combined with chemical control is most effective for moderate to large-scale strawberry producers. Control efforts should begin by eliminating environments that provide shelter and breeding sites for slugs. This includes removing excess mulch, debris piles, boards, rocks, and compost heaps from areas near the field [19].

Japanese beetle adults

Adult Japanese beetles are metallic green to bronze insects, approximately 0.5 inches long. They are generally not major pests of June-bearing strawberries unless large numbers feed on foliage late in the season. However, for ever bearing varieties, adults can damage fruit by creating holes. These beetles may also fall into harvest containers, where they tend to crawl to the bottom to hide (Fig.11). Japanese beetles produce a single generation each year, but adults do not all emerge simultaneously and are capable of flying long distances. Individual adults live for 30–45 days, so control measures may need to be maintained for up to two months. The larvae feed on roots during late summer and into late fall [18].

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Fig.11. Japanese Beetle on Strawberry Flower.

Control

No cultural practices have proven highly effective against Japanese beetles. Since pheromone traps can attract even more beetles into the field, control is best achieved through hand-picking or applying treatments when the first beetles appear to help reduce populations. Only a few insecticides are registered for use on strawberries, and the most effective options often have long pre-harvest intervals, limiting their use during the harvest period [19].

Cyclamen mite

Cyclamen mites are extremely small and cannot be seen without at least 20X magnification. The first signs of infestation are usually the feeding symptoms, small, distorted, and off-color new leaves, which are typically noticed before the mites themselves are, detected (Fig.12). If populations increase, affected plants can become unproductive. Cyclamen mites are often introduced into fields on nursery plants and can also be spread via workers' hands or tools. Biological control using predatory mites can help manage cyclamen mite populations [19].

Fig.12. Cyclamen Mite Damage on Strawberry Foliage.

Conclusion

Strawberry cultivation is increasingly constrained by a wide spectrum of diseases caused by fungal, oomycete, bacterial and soil-borne pathogens, often aggravated by insect pests that directly damage plants and indirectly facilitate pathogen entry and spread. The present review highlights that root and crown rots, anthracnose, gray mold, powdery mildew

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and leaf spot complexes remain the most destructive diseases across diverse production systems, while insects such as tarnished plant bug, leafhopper, sap beetle, Japanese beetle, slugs and cyclamen mites further compromise yield and fruit quality. Conventional dependence on calendar-based chemical control, though sometimes effective in the short term, has proven inadequate and unsustainable due to the emergence of resistance, residue concerns, environmental risks and rising production costs. Evidence synthesized in this review clearly indicates that integrated disease management (IDM), supported by sound integrated pest management (IPM) principles, offers the most reliable and environmentally responsible approach for sustainable strawberry production. The use of disease-free planting materials, crop rotation, well-drained soils, sanitation, canopy and moisture management, biological control agents and rational, need-based application of fungicides and insecticides collectively reduces disease pressure while maintaining productivity and fruit quality. In subtropical regions such as Bangladesh, successful implementation of IDM is particularly critical due to favorable conditions for pathogen development, limited access to resistant cultivars and insufficient availability of certified planting materials.

Future progress in strawberry disease management will depend on strengthening local research on pathogen and pest diversity, improving nursery certification systems, developing resistant or tolerant cultivars and enhancing farmer awareness through effective extension services. Greater emphasis should also be placed on eco-friendly alternatives, including biocontrol agents and botanicals, to reduce reliance on synthetic chemicals. Overall, the adoption of integrated, knowledge-based management strategies is essential to ensure disease-free strawberry production, long-term sustainability and economic viability of this high-value crop.

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