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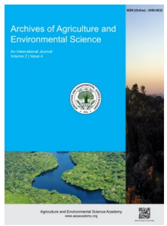

REVIEW ARTICLE

Major diseases of rice in Asia: Occurrence, impact, and management strategies with special focus on south Asia

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ABSTRACT

Rice (*Oryza sativa* L.) is the principal staple food of South Asia, supporting the livelihoods and nutrition of over 1.8 billion people across India, Bangladesh, Nepal, Pakistan, and Sri Lanka. Despite its critical importance, rice production in the region is persistently undermined by a wide spectrum of diseases caused by fungi, bacteria, viruses, and nematodes, which collectively cause yield losses ranging from 10 to 80 percent annually. This review aims to synthesize the current status, epidemiology, economic impact, and management of the major rice diseases of South Asia, and to highlight the role of emerging artificial intelligence (AI) tools for sustainable disease control. Ten major diseases were classified into four causal-agent groups, and seven of greatest economic significance were analyzed in detail Rice Blast (*Magnaporthe oryzae*), Bacterial Leaf Blight (*Xanthomonas oryzae* pv. *oryzae*), Sheath Blight (*Rhizoctonia solani*), Brown Spot (*Bipolaris oryzae*), False Smut (*Ustilaginoidea virens*), Bakanae (*Fusarium fujikuroi*) and Rice Tungro Virus. Maximum reported yield losses were 80% for Rice Tungro, 70% for Rice Blast, 60% for Bacterial Leaf Blight, 50% for Sheath Blight and 58% for Brown Spot, with an estimated regional economic burden of US$ 4–10 billion per year. Thus, integration of host resistance with AI-assisted, edge-deployable diagnostic systems offers a region-specific and climate-adaptive pathway for sustainable rice disease management in South Asia, distinct from the chemical-centric approaches that have so far dominated the region.

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INTRODUCTION

Rice is the foundation of food security in South Asia, and its importance to the region is difficult to overstate. Across the five countries covered in this review India, Bangladesh, Nepal, Pakistan, and Sri Lanka rice is not simply a crop but a cultural institution that shapes agricultural calendars, national trade policies, and the daily diets of billions of people. The region produces roughly 410 million metric tons of paddy per year, representing approximately 40 percent of global rice output (FAO, 2023). In Bangladesh, per capita rice consumption exceeds 170 kilograms per year. In Nepal, rice farming occupies about 1.47 million hectares and contributes roughly 20 percent of agricultural GDP (MoALD, 2022). Pakistan cultivates rice largely for export, particularly the aromatic basmati varieties, while Sri Lanka depends on rice for over 45 percent of its national caloric needs. Against this backdrop, rice diseases represent one of the most serious and least adequately addressed threats to food security in South Asia. Diseases caused by fungi, bacteria, viruses, and nematodes collectively reduce annual rice yields by 10 to 80 percent, depending on the pathogen, the variety grown, and the weather conditions of the season. The historical record makes the stakes clear: the Great Bengal Famine of 1943, which killed an estimated two to three million people, was caused in significant part by a severe epidemic of brown spot that devastated the Bengal rice crop under conditions of wartime food system failure (Padmanabhan, 1973). Today, the cumulative annual cost of rice diseases to South Asia is estimated at four to ten billion US dollars when direct yield losses, grain quality penalties, fungicide costs, and seed replacement expenses are combined (Singh *et al*., 2016).

The severity of the disease problem in South Asia has been worsened by the transformations of modern rice farming. The adoption of high-yielding varieties, intensive nitrogen fertilization, and high planting densities during the Green Revolution drove dramatic yield gains but simultaneously created growing conditions highly favorable to disease. High nitrogen inputs promote the lush, dense canopies that fungal pathogens exploit. Genetic uniformity over large areas allows virulent pathogen races to spread without resistance barriers. Climate change adds further pressure by altering temperature and rainfall patterns in ways that expand the geographic range of some pathogens, shift disease seasons, and create new epidemic windows (Chakraborty & Newton, 2011). Although several reviews on rice diseases of Asia are available, most have focused either on a single pathogen or on Southeast Asian production systems, and they have rarely integrated South-Asia-specific genetic resources, the recent advances in AI-based plant disease diagnosis and the implications of changing crop establishment systems such as dry direct-seeded rice (DDSR). The present review addresses this research gap by combining (i)a country-wise comparative analysis of seven economically most important rice diseases across India, Bangladesh, Nepal, Pakistan and Sri Lanka; (ii) recent field and genomic evidence from Nepalese landraces (Lamsal *et al*., 2024; Ghimire *et al*., 2026); and (iii) emerging AI- and sensor-based disease management tools. The specific aim of this review is therefore to provide an evidence-based, regionally grounded synthesis of the occurrence, epidemiology, yield losses and management of the major rice diseases of South Asia, and to identify priority research gaps for the next decade.

METHODOLOGY

This review was developed as a critical synthesis of peer-reviewed and grey literature on rice diseases of South Asia. Relevant publications were retrieved from Web of Science, Scopus, Google Scholar, PubMed, ScienceDirect and the AGRIS database. The Boolean search strings used included combinations of "rice" OR "*Oryza sativa*" with "disease", "blast", "bacterial leaf blight", "sheath blight", "brown spot", "false smut", "bakanae", "tungro", "South Asia", "India", "Nepal", "Bangladesh", "Pakistan", "Sri Lanka", "integrated disease management", "host resistance", "artificial intelligence" and "deep learning". Government and institutional reports were also consulted, including those of the Food and Agriculture Organization (FAO), the International Rice Research Institute (IRRI, 2022), the Indian Council of Agricultural Research (ICAR), the Bangladesh Rice Research Institute (BRRI), the Nepal Ministry of Agriculture and Livestock Development (MoALD) and the Government of Pakistan (GoP, 2022). Articles published in English, with full-text availability and clear methodological description, were preferred. Publications were screened first by title and abstract, and then by full text, and were retained only when they reported (a) original field, glasshouse or molecular data; (b) regional or country-level disease surveys; or (c) management evaluations relevant to South Asian rice systems. Where conflicting yield-loss or epidemiological values were reported, the range and the most recent multi-location estimates were preferred. The selected literature was then classified by pathogen, country and management strategy, and synthesized into the comparative figures and tables presented in this review.

CLASSIFICATION OF MAJOR RICE DISEASES

The major rice diseases of South Asia fall into four broad categories based on the type of organism that causes them: fungal, bacterial, viral, and nematode-associated diseases. This classification has direct practical relevance because the management strategies, diagnostic approaches, and epidemiological risk factors differ fundamentally between categories. Figure 1-5 presents a comprehensive classification tree of the major rice diseases recognized in South Asia, organized by causal agent. Table 1-5 provides a structured summary of all ten diseases discussed in this review. Fungal diseases are by far the most numerous and economically damaging category. Rice blast, sheath blight, brown spot, false smut, bakanae, and stem rot all belong to this group. Bacterial diseases principally bacterial leaf blight (BLB) and bacterial leaf streak are severe in irrigated lowland systems where irrigation water serves as a dispersal route. Rice Tungro, a viral disease, is episodic but capable of catastrophic losses when its leafhopper vectors peak in abundance. Nematode-associated diseases, including white tip nematode and root-knot nematode, cause moderate but consistent damage particularly in areas with poor seed quality control.

MAJOR RICE DISEASES: OCCURRENCE, EPIDEMIOLOGY AND YIELD LOSSES

Rice blast: Rice blast, caused by *Magnaporthe oryzae* B. Couch and Kohn (anamorph: *Pyricularia oryzae* Cavara), is the most destructive rice disease in South Asia and worldwide. It is present in virtually every rice-growing district of India, with the heaviest incidence in the highland states of Uttarakhand, Assam, Odisha and the north-eastern hills, where cool nights and persistent mist create near-ideal infection conditions (Bonman, 1992). In Nepal, blast is the most feared disease among hill farmers, with regular epidemics in the mid-hill districts. Blast attacks rice at every growth stage. Leaf blast produces spindle-shaped lesions with pale-grey centers and dark-brown borders. Node blast causes blackening and collapse of internodes, leading to lodging. Neck blast, the most economically damaging form, infects the peduncle just below the panicle, cutting off water and nutrient supply to developing grains. The fungus spreads through wind-borne conidia that germinate and form appressoria capable of mechanically penetrating the leaf cuticle under turgor pressure, a process that requires melanin biosynthesis (Howard & Valent, 1996). Infection is most rapid at 24–28 °C with relative humidity above 93% and leaf wetness for at least 10 h. The pathogen's extreme race diversity is a central challenge: more than 300 races have been identified globally, and major resistance genes are routinely overcome within three to five years of large-scale variety release (Bonman, 1992). Annual yield losses in India have been estimated at 5–10 million metric tons of paddy (Singh *et al.*, 2016). In susceptible varieties at the early grain-filling stage, neck blast can cause up to 100% yield loss (Skamnioti & Gurr, 2009). In Nepal, losses of 40–60% have been recorded in susceptible hill varieties during high-blast years (Sharma *et al.*, 2017).

Bacterial leaf blight: Bacterial leaf blight (BLB), caused by *Xanthomonas oryzae* pv. *oryzae*, is the foremost bacterial disease of rice in South Asia. It is endemic across the major rice-growing areas of India, Bangladesh, Pakistan, Nepal and Sri Lanka (Mew *et al.*, 2004; Niño-Liu *et al.*, 2006). BLB produces two syndromes: kresek, a systemic seedling wilt, and leaf blight, characterized by water-soaked yellowing lesions spreading from leaf margins inwards. The bacterium enters through hydathodes and spreads via irrigation water, wind and wounds. Epidemics are promoted by temperatures of 25–35 °C, high humidity, flooding and excess nitrogen. Eleven pathogenic races have been described in Asia, with considerable diversity in South Asia (Vera Cruz *et al.*, 2000). Yield losses range from 10 to 60%, with averages of 20–30% in susceptible varieties under high-nitrogen management.

Sheath blight: Sheath blight, caused by *Rhizoctonia solani* Kuhn AG1-IA, has become one of the most widespread rice diseases in South Asia over the past four decades, a rise that is directly attributable to the intensification of rice farming under high-yielding-variety cultivation. It is now a major constraint in India, Bangladesh, Sri Lanka and the Terai region of Nepal (Mew *et al.*, 2004; Savary *et al.*, 2000). Notably, no commercially released variety is fully immune, which makes sheath blight uniquely dependent on chemical and cultural management. Initial symptoms appear near the waterline as oval lesions with greyish-white centers and dark-brown borders. The pathogen spreads via soil sclerotia that floats in floodwater and infects neighboring plants by direct hyphal contact. Temperatures of 28–32 °C and relative humidity above 90% are optimal for epidemic development. Yield losses range from 20 to 50% and can exceed 50% in wet season crops under heavy nitrogen management (Savary *et al.*, 2000).

Brown spot: Brown spot, caused by *Bipolaris oryzae* (Breda de Haan) Shoemaker, is historically the most notorious rice disease of South Asia, widely regarded as a contributing cause of the 1943 Bengal Famine (Padmanabhan, 1973). At present, it remains a significant problem in rain-fed, nutrient-deficient systems, and is most prevalent in Nepal, eastern India and Bangladesh, where soils are commonly deficient in nitrogen, potassium and silicon. The disease produces oval leaf lesions with brown centers and yellow halos, and infects glumes, causing grain discoloration that reduces market value. Lamsal *et al.* (2024) conducted a systematic field evaluation of 54 Nepalese rice landraces at Rampur, Chitwan, revealing substantial variation in brown-spot susceptibility and identifying landraces with meaningful field tolerance resources of direct value to resistance-breeding programs. The molecular and phenotypic diversity documented by Ghimire *et al.* (2026) provides the genomic framework needed to convert this field-level tolerance into marker-assisted selection targets. Yield losses range from 6 to 58%, with averages of 15–25% in susceptible varieties under nutrient stress (Ou, 1985; Mew *et al.*, 2004).

False smut: False smut, caused by *Ustilaginoidea virens* (Cooke) Takahashi, is an increasingly common disease across South Asia, with growing incidence in India's rice-producing states and rising reports from Nepal and Bangladesh. The pathogen converts individual florets into large orange yellow to greenish-black powdery chlamydospore masses. Beyond direct yield losses of 1–10%, false smut produces ustiloxin mycotoxins that are toxic to livestock and potentially harmful to humans, making grain quality and food safety concerns more significant than the direct yield impact (Ladhalakshmi *et al.*, 2012). The disease is favored by temperatures of 24–32 °C and high humidity during booting to flowering.

Bakanae: Bakanae, caused by *Fusarium fujikuroi* Nirenberg, is a seed-borne disease that produces two distinct syndromes. In the bakanae syndrome, the pathogen overproduces gibberellins, causing infected seedlings to elongate abnormally and eventually die. Foot rot causes dark-brown basal stem lesions that lead to plant death. The disease occurs throughout India, Bangladesh and Pakistan, and is particularly damaging in nursery beds. Yield losses range from 5 to 30% (Ou, 1985). Seed treatment with carbendazim at 0.2% concentration is an effective and low-cost management measure.

Rice Tungro Virus: Rice tungro disease (RTD) is caused by the concerted infection of two unrelated viruses Rice Tungro Spherical Virus (RTSV) and Rice *Tungro Bacilliform Virus* (RTBV) transmitted by the green leafhopper *Nephotettix virescens* Distant and related species (Hibino, 1996). RTD is most prevalent in southern India, Bangladesh and Sri Lanka, and occurs episodically when leafhopper populations peak coincidentally with susceptible crop growth stages. Infected plants display characteristic yellow-orange leaf discoloration, severe stunting and reduced tillering. Yield losses can reach 80% in epidemic years in susceptible varieties. Management relies on leafhopper vector control through insecticides such as imidacloprid, combined with host resistance, synchronized planting and rouging of infected plants (Savary *et al.*, 2019).

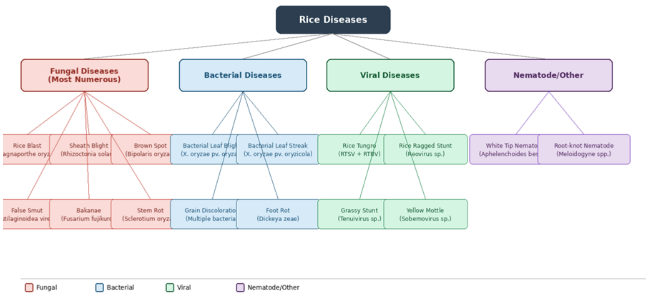

Figure 1. *Classification of major rice diseases by causal agent type in South Asia. Colour coding: red = fungal, blue = bacterial, green = viral, purple = nematode/other.*

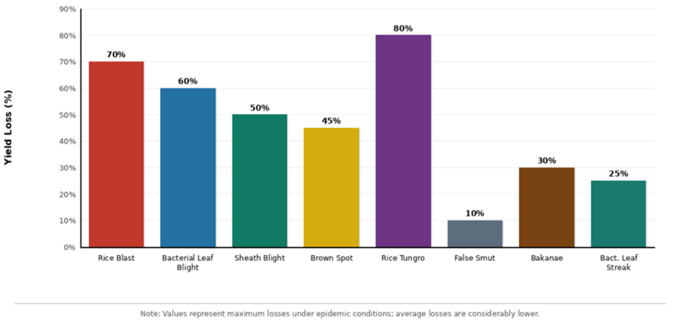

Figure 2. *Maximum documented yield losses (%) caused by major rice diseases in South Asia. Bars represent maximum values from published field studies under epidemic conditions.*

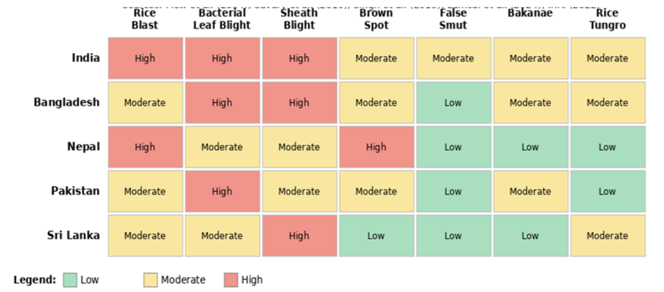

Figure 3. *Disease prevalence comparison across South Asian rice-growing countries. High (red) = frequent epidemic occurrence; Moderate (amber) = periodic or localized outbreaks; Low (green) = rare or negligible incidence. BLB = Bacterial Leaf Blight.*

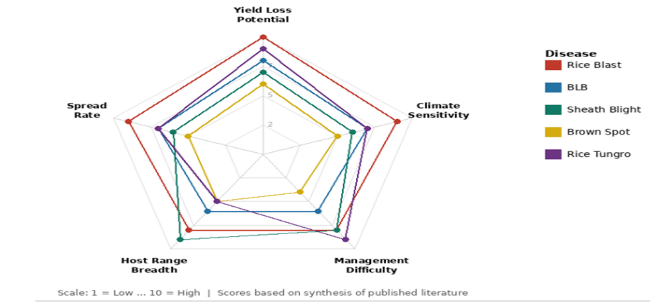

Figure 4. *Radar chart comparing the epidemiological severity profiles of five major rice diseases across five dimensions. Scale: 1 (low) to 10 (high). Scores synthesized from published literature.*

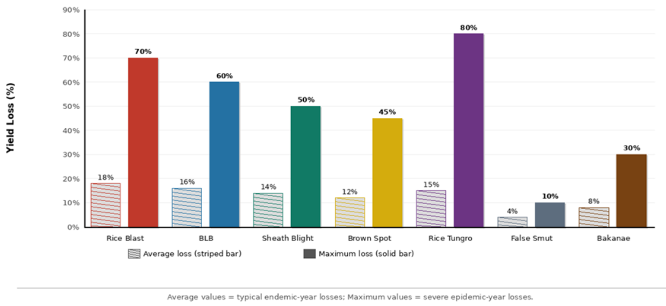

Figure 5. *Average (striped bars) versus maximum (solid bars) documented yield losses (%) for major rice diseases in South Asia. The gap between average and maximum represents the magnitude of epidemic risk.*

YIELD LOSS COMPARISON

Figure 2 presents the maximum documented yield losses caused by the major rice diseases in South Asia, based on a synthesis of published field studies and multi-location trial data. Rice tungro shows the highest maximum loss, up to 80% in epidemic years, reflecting its catastrophic potential when leafhopper populations surge on susceptible varieties. Rice blast follows at up to 70%, with its most damaging expression through neck blast at grain filling. BLB and sheath blight cause maximum losses of 60% and 50%, respectively. Brown spot reaches 45–58% under severe nutrient stress. False smut records the lowest direct loss, at 10%, but carries disproportionate food-safety significance through mycotoxin contamination. These results highlight a methodological problem in the regional literature: yield-loss values reported across studies are often based on artificial inoculation in single-season experiments and may overestimate -scale losses experienced by smallholders. Multi-season, multi-location farmer-participatory loss estimation remains an under-examined area of research in South Asia.

COUNTRY-LEVEL DISEASE PREVALENCE

Figure 3 presents a color-coded heatmap comparing the prevalence of seven major rice diseases across the five South Asian countries, classified as High, Moderate or Low based on published national disease surveys, IRRI assessments and country-specific studies (IRRI, 2022). India and Bangladesh carry the heaviest multi-disease burden, with three or more diseases rated High. Nepal's profile is dominated by blast and brown spot, driven by its montane agroecology and nutrient-poor soils, with relatively lower sheath blight pressure consistent with the lower nitrogen-use intensity in traditional hill farming systems (Lamsal *et al.*, 2024). Pakistan's profile reflects its irrigated basmati production system, which confers elevated BLB and bakanae risk. Sri Lanka shows high sheath blight and rice tungro pressure in its irrigated wet-zone systems. It is important to note that direct cross-country comparisons remain difficult because national survey methodologies, sampling intensities and rating scales are not standardized as a persistent gap that warrants the establishment of a harmonized regional rice-disease surveillance protocol.

EPIDEMIOLOGICAL SEVERITY PROFILES

Figure 4 presents a radar chart comparing five major diseases across five epidemiological dimensions: yield loss potential, spread rate, host range breadth, management difficulty and climate sensitivity, scored on a 1–10 scale based on a synthesis of the published literature. Rice blast scores highest on yield loss, spread rate and climate sensitivity, making it the most dynamic and unpredictable pathogen of the group. Rice tungro ranks highest on management difficulty, because it requires vector control rather than direct fungicide application. Sheath blight scores highest on host range breadth, with *Rhizoctonia* *solani* infecting more than 200 plant species, which limits the effectiveness of crop rotation. Brown spot scores lower on spread rate but is uniquely linked to soil nutrient deficiency, which makes it directly amenable to agronomic management a finding with practical implications for Nepal's nutrient-stressed farming systems (Lamsal *et al*., 2024).

AVERAGE VERSUS MAXIMUM YIELD LOSS

Figure 5 illustrates the difference between typical endemic-year losses and severe epidemic-year losses. Rice blast shows the largest absolute gap between average (approximately 18%) and maximum (70%), reflecting its high epidemic potential under virulent-race and conducive-weather combinations. Rice tungro shows an even more extreme maximum (80%) despite a moderate average, because epidemics depend entirely on vector population dynamics. False smut shows a narrow gap, consistent with its character as a steady, moderate-impact problem rather than an epidemic threat. These distinctions have direct implications for resource allocation in disease management: diseases with large average-to-maximum gaps warrant investment in early-warning systems and emergency response capacity, while diseases with small gaps are better addressed through routine integrated management. Conflicting reports exist in the literature regarding the absolute magnitude of these losses, particularly for sheath blight, where some studies report losses below 20% even under disease pressure that other authors classify as "severe". This inconsistency reinforces the need for standardized loss-assessment scales in the region.

Table 1. Major rice diseases in South Asia: Causal agent, pathogen type, mode of spread, yield loss range and geographic distribution.

Disease	Causal agent	Pathogen type	Mode of spread	Yield loss (%)	Primary countries
Rice Blast	*Magnaporthe oryzae*	Fungal	Wind-borne conidia; infected seed	10–70	India, Nepal, Bangladesh, Pakistan, Sri Lanka
Bacterial Leaf Blight (BLB)	*Xanthomonas oryzae pv. oryzae*	Bacterial	Irrigation water; wind; hydathodes	10–60	India, Bangladesh, Pakistan, Nepal
Sheath Blight	*Rhizoctonia solani* AG1-IA	Fungal	Soil sclerotia; flood water	20–50	India, Bangladesh, Sri Lanka, Nepal
Brown Spot	*Bipolaris oryzae*	Fungal	Air-borne conidia; seed-borne	6–58	Nepal, India (East), Bangladesh
False Smut	*Ustilaginoidea virens*	Fungal	Air-borne chlamydospores	1–10	India (Punjab, Haryana), Nepal
Bakanae	*Fusarium fujikuroi*	Fungal	Seed-borne; soil-borne	5–30	India, Bangladesh, Pakistan
Bacterial Leaf Streak	*X. oryzae pv. oryzicola*	Bacterial	Wind-driven rain; infected seed	5–25	India, Bangladesh
Rice Tungro	RTSV + RTBV	Viral	Green leafhopper (Nephotettix spp.)	Up to 80	India (South), Bangladesh, Sri Lanka
Stem Rot	*Sclerotium oryzae*	Fungal	Soil-borne sclerotia	10–30	India (coastal), Bangladesh
White Tip Nematode	*Aphelenchoides besseyi*	Nematode	Seed-borne	10–20	India, Bangladesh, Nepal

Sources: Mew *et al.* (2004); Ou (1985); Savary *et al.* (2019); Niño-Liu *et al.* (2006); Hibino (1996); Lamsal *et al.* (2024).

Table 2. Comparative analysis of six major rice diseases in South Asia: Favorable conditions, yield loss range, severity ranking and key references.

Disease	Causal agent	Favourable conditions	Yield loss (%)	Rank	Key Reference
Rice Blast	*Magnaporthe oryzae*	24–28 °C; RH > 93%; leaf wetness > 10 h; high N	10–70 (up to 100)	1st	Skamnioti & Gurr (2009)
BLB	*X. oryzae pv. oryzae*	28–35 °C; RH > 80%; flooding; high N	10–60; avg. 20–30	2nd	Niño-Liu *et al.* (2006)
Sheath Blight	*Rhizoctonia solani*	28–32 °C; dense canopy; RH > 90%	20–50; can exceed 50	3rd	Savary *et al.* (2000)
Brown Spot	*Bipolaris oryzae*	25–30 °C; nutrient-deficient soils; RH 86–100%	6–58; avg. 15–25	4th	Lamsal *et al.* (2024)
Rice Tungro	RTSV + RTBV	25–30 °C; leafhopper abundance at heading	Up to 80 in epidemics	2nd (epidemic)	Hibino (1996)
False Smut	*Ustilaginoidea virens*	24–32 °C; high RH during booting to heading	1–10 direct	5th	Ladhalakshmi *et al.* (2012)

Table 3. Recommended chemical, biological and varietal management tools for major rice diseases in South Asia.

Disease	Fungicide / Bactericide	Biocontrol agent	Resistant varieties in South Asia
Rice Blast	Tricyclazole (0.06%); Isoprothiolane; Carbendazim; Azoxystrobin	*Trichoderma harzianum; Bacillus subtilis; Pseudomonas fluorescens*	IR64; PR106; Swarna Sub1; Pusa Basmati 1121; BG300-1 (Sri Lanka); tolerant Nepalese landraces (Lamsal *et al.*, 2024; Ghimire *et al.*, 2026)
BLB	Copper oxychloride (0.3%) + Streptomycin; Kasugamycin	*Pseudomonas fluorescens Pf1; Bacillus subtilis*	BRRI dhan29 (Bangladesh); Improved Samba Mahsuri with Xa21; IR20; Pusa 44
Sheath Blight	Validamycin (3%); Hexaconazole (0.1%); Propiconazole	*Trichoderma viride; T. harzianum*	No immune variety; moderate tolerance in IRBB60; QTL mapping ongoing
Brown Spot	Mancozeb (0.25%); Iprodione; Chlorothalonil	*Bacillus amyloliquefaciens; Trichoderma spp.*	CO43; tolerant Nepalese landraces (Lamsal *et al.*, 2024)
False Smut	Propiconazole at boot-leaf stage; copper fungicides	Limited published data for South Asia	IR36; tolerant lines under screening
Bakanae	Carbendazim seed treatment (0.2%); Thiophanate-methyl	*Trichoderma viride* as seed treatment	BR6 (Bangladesh); tolerant accessions under selection
Rice Tungro	Imidacloprid for leafhopper vector; no direct antiviral	Roguing of infected plants; synchronised planting	ARC10550 (resistant); IR64 and IR8 (moderate); TN1 (highly susceptible)

Table 4. Best Management Practice (BMP) quick-reference guide for rice disease management in South Asian smallholder farming systems.

Practice	Recommended action	Target disease
Seed treatment	Hot water at 52 °C for 10 min OR carbendazim/thiram seed dressing	Brown Spot, Bakanae, BLB
Balanced fertilization	Avoid excess N; apply K and Si on deficient soils	Blast, Sheath Blight, Brown Spot, False Smut
Water management	Alternate Wetting and Drying (AWD); avoid prolonged waterlogging	BLB, Sheath Blight, Stem Rot
Planting density	Optimum spacing 20 × 15 cm for transplanted rice	Sheath Blight, Blast
Field sanitation	Plough in or burn infected crop residues after harvest	All diseases
Crop rotation	Rotate with legumes or vegetables to break soil-borne pathogen cycles	Sheath Blight, Stem Rot, Bakanae
Disease scouting	Weekly field scouting; apply fungicide at economic threshold only	All diseases
Biological control	Trichoderma or Bacillus seed treatment and soil drench at transplanting	Blast, Sheath Blight, Brown Spot
Vector management	Imidacloprid at early tillering to suppress green leafhopper	Rice Tungro

Table 5. Modern technologies for rice disease identification and their current status and application in South Asian rice pathology.

Tool / Technology	Key capabilities	Development stage	Application in rice pathology
Deep Learning (CNN, ResNet, VGG)	Automated lesion detection from field images; >95% accuracy on benchmark datasets	Research to early commercial	Blast, brown spot and BLB symptom classification from smartphone images
Hyperspectral / Multispectral Imaging	Detects sub-visual spectral changes before visible symptoms; covers large field areas by drone or satellite	Research (field validation needed)	Pre-symptomatic blast and sheath blight detection; stress mapping
Transformer-based Vision Models (ViT, Swin)	Captures long-range feature dependencies; outperforms CNNs on heterogeneous field images	Active research	Cross-disease, multi-crop detection systems for South Asian field conditions
Multimodal Sensor Fusion	Combines RGB, near-infrared, thermal and weather data for multi-cue diagnosis	Research prototype	Integrating disease risk prediction with weather data for early-warning systems
Explainable AI (XAI)	Generates decision explanations; identifies key features driving diagnosis	Research	Supports extension workers and farmers in understanding AI recommendations
Edge AI / Smartphone Apps	On-device inference without cloud connectivity; accessible to smallholder farmers	Early commercial	Field-deployable blast and BLB identification tools for Nepal, Bangladesh and India

IMPACT ON YIELD AND FOOD SECURITY

The aggregate impact of rice diseases on South Asian food security is very large. Savary *et al.* (2019), in a landmark global analysis, estimated that diseases account for an average yield gap of approximately 30% in Asian rice production systems, with fungi contributing the largest share. In monetary terms, the annual cost to South Asia combining direct yield losses, grain quality penalties, fungicide expenditure and seed-replacement expenses is estimated at US$ 4–10 billion (Singh *et al.*, 2016). India, producing roughly 120 million metric tons of paddy annually, loses an estimated 15–20 million metric tons to disease each year sufficient to meet the annual food needs of more than 100 million people. Bangladesh, where rice provides approximately 70% of national caloric intake, loses 10–15% of its annual harvest to disease. In Nepal, losses from blast and brown spot in susceptible hill varieties can reach 20–30%, with serious implications for food security in remote mountain communities (Sharma *et al.*, 2017; Lamsal *et al.*, 2024). Pakistan's losses are concentrated in high-value basmati production, where BLB infection reduces export quality and revenues even when direct yield loss is moderate. The socio-economic dimension of these losses is equally significant. More than 80% of rice producers in South Asia are smallholder farmers cultivating less than two hectares, without crop insurance or financial buffers to absorb disease-induced income shocks. A single severe epidemic can force households to sell productive assets, withdraw children from school or take on debt that takes years to repay.

MANAGEMENT STRATEGIES

Cultural practices

Cultural practices form the most accessible and affordable foundation of rice disease management. Key evidence-based measures include the following:

Seed sanitation: certified, disease-free seed eliminates seed-borne pathogens including *Bipolaris oryzae*, *Xanthomonas oryzae* and *Fusarium fujikuroi*. Hot-water treatment at 52 °C for 10 min is effective and requires no chemical inputs.

Balanced fertilization: avoiding excessive nitrogen application is one of the most effective ways of reducing the risk of blast, sheath blight and false smut. Adequate potassium and silicon nutrition significantly reduces brown-spot susceptibility in nutrient-poor soils, as demonstrated by Lamsal *et al.* (2024) in Nepalese field conditions.

Water management: alternate wetting and drying (AWD) irrigation reduces standing-water duration, limiting the irrigation-water-mediated spread of BLB and the flooded conditions that favor sheath blight and stem rot.

Planting density: a recommended spacing of 20 × 15 cm for transplanted rice improves canopy aeration and reduces the humid microclimate that promotes fungal diseases.

Crop establishment and weed management: Adhikari *et al.* (2019) demonstrated at Rampur, Chitwan, Nepal, that the crop establishment method significantly influences weed dynamics and the pathogen host environment in DDSR systems, providing an empirical basis for disease-risk assessment in these emerging cropping practices.

Chemical control

Fungicides and bactericides are the most rapidly effective tools in epidemic situations. Key principles include:

Rice blast: tricyclazole at 0.06% is the standard recommendation across South Asia. Isoprothiolane, carbendazim and azoxystrobin are alternatives. Prophylactic application at the boot-leaf stage protects against neck blast (Singh, 2013).

BLB: Copper oxychloride at 0.3% combined with streptomycin sulfate is the primary recommendation. However, the field efficacy of bactericides is inconsistent, and host resistance remains the preferred long-term strategy (Niño-Liu *et al.*, 2006).

Sheath blight: validamycin at 3% is the most cost-effective and specifically active option. Hexaconazole, propiconazole and tebuconazole are systemic alternatives. Application should begin at active tillering, before disease establishment (Kotamraju, 2010).

Brown spot: mancozeb at 0.25%, iprodione and chlorothalonil are recommended. Importantly, improving soil nutrition often reduces brown-spot severity without requiring fungicide application, which is more sustainable in nutrient-poor farming systems (Lamsal *et al.*, 2024).

Rice tungro: vector control using imidacloprid applied in nurseries and at early tillering is the primary strategy. No direct antiviral treatments are commercially available.

Biological control

Biological control agents with demonstrated efficacy under South Asian field conditions include:

***Trichoderma harzianum* and *T. viride*:** seed treatment and soil application at transplanting have reduced sheath blight and brown spot severity by 30–50% in field trials in India and Bangladesh (Yadav *et al.*, 2018).

***Bacillus subtilis* and *B. amyloliquefaciens*:** these rhizobacteria produce antifungal lipopeptides active against *M. oryzae* and *R. solani*. Seed priming has reduced blast severity by 30–40% in Indian field trials (Amruta *et al.*, 2019).

***Pseudomonas fluorescens*:** well, documented for BLB and blast suppression through siderophore production, antibiosis and induced systemic resistance. Several strains are registered as biocontrol agents in India (Sharma *et al.*, 2017).

Host resistance

Host resistance is the most cost-effective, ecologically sound and durable disease management strategy. For rice blast, more than 100 *Pi* resistance genes have been identified, and pyramiding multiple *Pi* genes through marker-assisted selection provides more durable resistance than single-gene deployment. The molecular and phenotypic diversity of Nepalese landraces documented by Ghimire *et al.* (2026) provides a valuable foundation for identifying blast and brown spot resistance donors from within Nepal's own genetic heritage. For BLB, *Xa* gene pyramid in varieties has demonstrated durable resistance against diverse *Xoo* races (Vera Cruz *et al.*, 2000). For brown spot, the field-level tolerance documented in Nepalese landraces by Lamsal *et al.* (2024) provides direct starting points for resistance gene mapping and marker-assisted breeding. Sheath blight remains an unsolved breeding challenge: no immune variety exists, and QTL-based tolerance breeding is ongoing but has not yet produced widely adopted resistant varieties.

AUTHORS' VIEWS ON FUTURE MANAGEMENT: MODERN TOOLS FOR DISEASE IDENTIFICATION

The management of rice diseases in South Asia is entering a new era shaped not only by advances in plant breeding and agronomy, but also by the convergence of artificial intelligence (AI), remote sensing and precision agriculture technologies that are beginning to transform how diseases are detected, monitored and managed at farm, landscape and regional scale. For decades, disease identification in South Asian rice systems has depended on the trained eye of extension agents and researchers a system that has serious limitations of scale, speed and geographic reach, particularly in the remote hill areas of Nepal, the coastal deltas of Bangladesh and the vast irrigated plains of India, where millions of smallholder farmers grow rice with minimal access to professional diagnostic support. Ghimire *et al.* (2026), in a comprehensive review published in *The Plant Pathology Journal*, documented the rapid advance of deep-learning architectures including Convolutional Neural Networks (CNNs), ResNet, VGG, Vision Transformer (ViT) and Swin Transformer models for automated plant disease detection and diagnosis. They demonstrated that well-trained deep-learning models can achieve disease-identification accuracies exceeding 95% on benchmark datasets, with Transformer-based architectures outperforming conventional CNNs on heterogeneous field images because of their capacity to capture long-range spatial dependencies across the image. This development has direct relevance for rice pathology: blast lesion detection from smartphone photographs, brown-spot classification and BLB symptom recognition have all been demonstrated using deep-learning approaches, which means that a smartphone application capable of reliably identifying these diseases from a field image is no longer a distant prospect but an emerging practical tool (Ghimire *et al.*, 2026; Mohanty *et al.*, 2016; Ferentinos, 2018).

Beyond image-based diagnosis, hyperspectral and multispectral imaging deployed on drones and satellites offers pre-symptomatic disease detection by capturing characteristic spectral reflectance changes in rice canopies. Blast infection, for instance, alters the red-edge reflectance profile days before visible lesions appear, enabling landscape-scale surveillance and early warning that no ground-based scouting system can replicate at comparable speed or coverage (Mahlein *et al.*, 2018; Zhang *et al.*, 2019). These sensor systems, when integrated with deep-learning classifiers in the multimodal sensing framework reviewed by Ghimire *et al.* (2026), can simultaneously process RGB imagery, near-infrared reflectance, thermal data and weather-station inputs to produce multi-cue disease risk assessments that are far more robust than any single-sensor approach. Explainability remains a legitimate concern for practical deployment. Explainable AI (XAI) techniques that generate human-readable rationales for a diagnosis highlighting which lesion features drove a blast versus brown-spot classification decision are essential for farmer trust, extension-worker adoption and regulatory acceptance, and Ghimire *et al.* (2026) identified XAI as a critical frontier requiring focused research investment. Connectivity constraints in rural South Asia, particularly in Nepal's hill districts and remote areas of Bangladesh and Pakistan, make edge AI deployment where inference runs on the device itself without cloud connectivity an essential design principle for equitable access to these technologies (Ghimire *et al.*, 2026; Barbedo, 2018).

Looking ahead, the authors view the integration of AI-based disease detection with real-time weather data streams and process-based epidemiological models as the most transformative near-term opportunity. Such systems could deliver district- or field-level rice blast, BLB and sheath blight risk forecasts analogous to weather services, triggering pre-positioned fungicide supply responses and community scouting campaigns that would reduce both disease losses and the unnecessary blanket applications which currently characterize chemical management in the region (Savary *et al.*, 2019; Chakraborty & Newton, 2011). Climate-adaptive recalibration of these predictive models will be essential as South Asian temperature and monsoon patterns continue to shift, and sustained investment in both disease-monitoring infrastructure and AI model development grounded in locally collected, regionally representative training datasets must therefore be treated as a strategic priority for South Asian national agricultural research systems and international partners alike.

Conclusion

This review critically examined the occurrence, epidemiology, economic impact and management of the major rice diseases of South Asia. Ten major diseases were classified into four causal-agent groups, and seven of greatest economic significance were analyzed in depth. Among them, Rice Tungro and Rice Blast emerged as the most damaging, with maximum yield losses of 80% and 70%, respectively, followed by BLB (60%), Brown Spot

(58%) and Sheath Blight (50%). The aggregate annual economic burden of rice diseases in South Asia was estimated at US$ 4–10 billion. Brown spot was found to be most severe in nutrient-deficient systems, particularly in Nepal, where the diverse landraces was evaluated and characterized that constitute underused resistance resources of regional breeding significance, while False Smut emerged as a rising priority not because of its direct yield loss but because of its mycotoxin contamination risk. Overall, the review concludes that an integrated management approach combining host resistance derived from regional landraces, balanced nutrient and water management, biological control agents, and AI-assisted, edge-deployable diagnostic systems offers the most viable, climate-adaptive pathway for sustainable rice disease management in South Asia. Future research priorities include developing climate-adaptive integrated disease management frameworks, accelerating marker-assisted resistance breeding using diverse genetic resources, establishing harmonized regional pathogen monitoring networks, scaling validated biocontrol formulations for farmer-level deployment, investigating the disease implications of DDSR adoption, establishing ustiloxin monitoring systems for false smut, and integrating AI-powered disease detection tools into accessible farmer-ready extension systems.

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REFERENCES

Adhikari, A., Sapkota, A., Regmi, P., Neupane, S., Sapkota, S., Ghimire, S., & Kandel, B. P. (2019). Effect of establishment method and different weed management practices on dry direct seeded rice (DDSR) at Rampur, Chitwan. *Journal of Agricultural Science and Engineering*, *1*(3), 332-344. https://jase.samipubco.com/article_179754.html

Amruta, N., Prasanna Kumar, M. K., Kandikattu, H. K., Sarika, G., Puneeth, M. E., Ranjitha, H. P., & Narayanaswamy, S. (2019). Bio-priming of rice seeds with novel bacterial strains, for management of seed borne *Magnaporthe oryzae* L. *Plant Physiology Reports*, *24*(4), 507-520. https://doi.org/10.1007/s40502-019-00492-6

Barbedo, J. G. A. (2018). Factors influencing the use of deep learning for plant disease recognition. *Biosystems Engineering*, *172*, 84–91. https://doi.org/10.1016/j.biosystemseng.2018.05.013

Bonman, J. M. (1992). Durable resistance to rice blast disease-environmental influences. *Euphytica*, *63*(1), 115-123. https://doi.org/10.1007/BF00023917

Chakraborty, S., & Newton, A. C. (2011). Climate change, plant diseases and food security: an overview. *Plant pathology*, *60*(1), 2-14. https://doi.org/10.1111/j.1365-3059.2010.02411.x

FAO. (2023). FAOSTAT: Food and Agriculture Data. Statistics Division, Food and Agriculture Organization of the United Nations, Rome. fao.org/faostat/en/

Ferentinos, K. P. (2018). Deep learning models for plant disease detection and diagnosis. *Computers and Electronics in Agriculture*, *145*, 311–318. https://doi.org/10.1016/j.compag.2018.01.009

Ghimire, S., Lamsal, R., Sankuratri, A., Lakkarsu, P., & Vutla, S. (2026). Artificial intelligence-driven plant disease detection and diagnosis: A comprehensive review of deep learning approaches, multimodal sensing technologies, and future perspectives in precision agriculture. *The Plant Pathology Journal*, *42* (2), 121. https://doi.org/10.5423/PPJ.RW.01.2026.0004

GoP. (2022). Agricultural statistics of Pakistan 2021–22. Ministry of National Food Security and Research, Government of Pakistan, Islamabad. https://www.pbs.gov.pk/wp-content/uploads/2020/07/merged_pdf.pdf

Hibino, H. (1996). Biology and epidemiology of rice viruses. Annual Review of Phytopathology, *34*(1), 249–274. https://doi.org/10.1146/annurev.phyto.34.1.249

Howard, R. J., & Valent, B. (1996). Breaking and entering: host penetration by the fungal rice blast pathogen *Magnaporthe grisea*. *Annual Reviews in Microbiology*, *50*(1), 491-512. https://doi.org/10.1146/annurev.micro.50.1.491

IRRI. (2022). World rice statistics online query facility. International Rice Research Institute, Los Baños, Philippines. http://ricestat.irri.org

Kotamraju, V. K. K. (2010). Management of sheath blight and enhancement of growth and yield of rice with plant growth-promoting rhizobacteria. Auburn University. https://etd.auburn.edu/handle/10415/2381

Ladhalakshmi, D., Laha, G. S., Singh, R., Karthikeyan, A., Mangrauthia, S. K., Sundaram, R. M., & Viraktamath, B. C. (2012). Isolation and characterization of *Ustilaginoidea virens* and survey of false smut disease of rice in India. *Phytoparasitica*, *40*(2), 171-176. https://doi.org/10.1007/s12600-011-0214-0

Lamsal, R., Ghimire, S., Yadav, R., & Manandhar, H. K. (2024). Response of Nepalese rice landraces to brown spot [*Bipolaris oryzae* (Breda de Haan) Shoemaker] at Rampur, Chitwan, Nepal. *Agronomy Journal of Nepal*, *8*, 203-212. https://doi.org/10.3126/ajn.v8i1.70892

Mahlein, A. K., Kuska, M. T., Behmann, J., Polder, G., & Walter, A. (2018). Hyperspectral sensors and imaging technologies in phytopathology: state of the art. *Annual Review of Phytopathology*, *56*(1), 535–558. https://doi.org/10.1146/annurev-phyto-080417-050100

Mew, T. W., Leung, H., Savary, S., Vera Cruz, C. M., & Leach, J. E. (2004). Looking ahead in rice disease research and management. *Critical Reviews in Plant Sciences*, *23*(2), 103-127. https://doi.org/10.1080/07352680490433231

MoALD. (2022). Statistical information on Nepalese agriculture 2020/21. Ministry of Agriculture and Livestock Development, Government of Nepal, Kathmandu. https://centralaglab.gov.np/sites/default/files/publication-file/STATISTICAL-INFORMATION-ON-NEPALESE-AGRICULTURE-2077-78-82136.pdf

Mohanty, S. P., Hughes, D. P., & Salathé, M. (2016). Using deep learning for image-based plant disease detection. *Frontiers in Plant Science*, *7*, 1419. https://doi.org/10.3389/fpls.2016.01419

Niño-Liu, D. O., Ronald, P. C., & Bogdanove, A. J. (2006). Xanthomonas oryzae pathovars: model pathogens of a model crop. *Molecular Plant Pathology*, *7*(5), 303-324. https://doi.org/10.1111/j.1364-3703.2006.00344.x

Ou, S. H. (1985). Rice diseases (2nd ed.). International Rice Research Institute, Los Baños, Philippines. pp 380. https://books.google.co.in/books/about/Rice_Diseases.html?id=-k3mewv9nMoC&redir_esc=y

Padmanabhan, S. Y. (1973). The great Bengal famine. *Annual Review of Phytopathology*, 11(1), 11–26. https://doi.org/10.1146/annurev.py.11.090173.000303

Savary, S., Willocquet, L., Elazegui, F. A., Castilla, N. P., & Teng, P. S. (2000). Rice pest constraints in tropical Asia: quantification of yield losses due to rice pests in a range of production situations. *Plantdisease*, *84*(3), 357-36. https://doi.org/10.1094/PDIS.2000.84.3.357

Savary, S., Willocquet, L., Pethybridge, S. J., Esker, P., McRoberts, N., & Nelson, A. (2019). The global burden of pathogens and pests on major food crops. *Nature Ecology & Evolution*, *3*(3), 430–439. https://doi.org/10.1038/s41559-018-0793-y

Sharma, P., Bora, L. C., Puzari, K. C., Baruah, A. M., Baruah, R., Talukdar, K., & Phukan, A. (2017). Review on bacterial blight of rice caused by *Xanthomonas oryzae* pv. oryzae: different management approaches and role of Pseudomonas fluorescens as a potential biocontrol agent. *International Journal of Current Microbiology and Applied Science*, *6*(3), 982-1005. https://doi.org/10.20546/ijcmas.2017.603.117

Singh, R., Sunder, S., & Kumar, P. (2016). Sheath blight of rice: current status and perspectives. *Indian Phytopathology*, *69*(4), 340-351.

Singh, S. (2013). Epidemiology and management of blast disease of rice. *Punjab Agricultural University, Ludhiana, India, Master's thesis, Punjab Agricultural University*. https://krishikosh.egranth.ac.in/items/f0ee4206-d615-4022-876f-80f9951ae934

Skamnioti, P., & Gurr, S. J. (2009). Against the grain: safeguarding rice from rice blast disease. *Trends in Biotechnology*, *27*(3), 141-150. https://doi.org/10.1016/j.tibtech.2008.12.002

Vera Cruz, C. M., Bai, J., Ona, I., Leung, H., Nelson, R. J., Mew, T. W., & Leach, J. E. (2000). Predicting durability of a disease resistance gene based on an assessment of the fitness loss and epidemiological consequences of a virulence gene mutation. *Proceedings of the National Academy of Sciences*, *97*(25), 13500-13505. https://doi.org/10.1073/pnas.25027199

Yadav, R. N., Mishra, D., Zaidi, N. W., Singh, U. S., & Singh, H. B. (2018). Bio-control efficacy of Trichoderma spp. against the major diseases of rice (*Oryzae sativa* L.). *International Journal of Agriculture, Environment and Biotechnology*, *11*(3), 543-548. https://doi.org/10.30954/0974-1712.06.2018.17

Zhang, X., Han, L., Dong, Y., Shi, Y., Huang, W., Han, L., González-Moreno, P., Ma, H., Ye, H., & Sobeih, T. (2019). A deep learning-based approach for automated yellow rust disease detection from high-resolution hyperspectral UAV images. Remote Sensing, *11*(13), 1554. https://doi.org/10.3390/rs11131554