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Review

Sesame Diseases and Pests: Assessment of Threats to the Establishment of an Australian Industry

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Abstract

The emerging sesame (*Sesamum indicum* L.) industry in Australia faces potential threats from multiple pre-harvest diseases and pests, which will necessitate an initiative-taking approach for pest management. Here we assess the diseases and pests most likely to impede the development of a viable Australian sesame industry. Drawing on the international literature, we also consider the management approaches most likely to be viable and identify key research gaps necessary for effective and sustainable crop protection. More than sixty-seven plant pathogens have been identified worldwide that cause diseases in sesame, with some being observed to be major in Australia. Part of this review aims to provide an extensive overview of previous research on sesame and its diseases, shedding light on the evolving knowledge within sesame research, emerging trends, and the current state of understanding on the topic as it applies to Australia. Among the hundreds of pests reported to attack sesame internationally, this review identifies fifty-six pest taxa that are established in, or native to, Australia. We rank those most likely to be serious based on overseas damage levels and observations from recent trial plantings in Northern Australia. Chemical control methods have demonstrated efficacy overseas but are associated with concerns over resistance and environmental impact. Extremely limited numbers of pesticides are currently registered for pest or disease control in sesame by the Australian Pesticides and Veterinary Medicines Authority so non-chemical methods will be important. These include botanical, biological, cultural, and physical control approaches. This review underscores the need for continued research and tailored plant protection strategies to optimize sesame.

Keywords: *Antigastra catalaunalis*; integrated pest management; integrated disease management biological control; oilseeds; shattering; dehiscent

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Academic Editor: Il-Ryong Choi

Received: 10 May 2025
Revised: 26 June 2025
Accepted: 7 July 2025
Published: 14 July 2025

Citation: Adorada, D.L.; Jones, L.C.; Liu, J.; Gurr, G.M. Sesame Diseases and Pests: Assessment of Threats to the Establishment of an Australian Industry. *Crops* **2025**, *5*, 44. https://doi.org/10.3390/crops5040044

1. Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest oilseed crops known to humanity. It is widely grown in subtropical and tropical regions around the world for its edible seeds, confectionery purposes, paste (tahini), edible oil, flour, and cake [1]. Sesame seed production and consumer demand have increased during the last decade. Due to changing food consumption behaviour, the availability of value-added products, such as oil, pharmaceuticals, and niche foods, and by-products such as sesame meals, demand for sesame is predicted to continue to increase. In the 1990s, Australia faced challenges in establishing a viable sesame industry due to the use of unsuitable, dehiscent varieties that led to seed loss from pod shattering that precluded mechanical harvesting. In 2018, new efforts were made to establish the industry using high-yielding, non-shattering sesame varieties. Research conducted by Decker and Bettina [2] on new and emerging agricultural industry opportunities and market scoping showed that sesame has enormous potential for Australia. Like all crops, however, diseases and pests are a major biotic threat to sesame production. Many of the pathogens and arthropod pests that attack this crop in overseas production areas are present in Australia. Each of these, as well as several native Australian species, present potentially serious barriers to the development of a profitable and sustainable sesame industry. Accordingly, we review the international literature and combine this with field records from our own research over the last two years, to identify the diseases and pests most likely to damage sesame under Australian conditions and impede the development of a viable industry. For the most serious diseases and pests, we also consider the management approaches most likely to be viable and identify key research gaps.

Due to the rising consumer's inclination towards healthy living and adopting healthy food ingredients, the sesame seed market is anticipated to grow [3]. Across the world, there is a growing demand for healthy ingredients in diets among consumers [4], especially the millennial population across North America and Europe. Thus, the key opportunities for sesame seeds also lie in the organic market [2], especially given a study in China showing that sesame oil, paste and meal grown under conventional agriculture contain pesticide residue that may reduce its nutritive value to consumers [5]. More consumers and importing nations seek to purchase organic, chemical-free products, and conventionally produced sesame oil, meal and paste. The global organic market was worth US$1.6 billion in 2015 and expected to grow at a compound annual growth rate exceeding 12–14% from 2024 to 2026 [2]. This can be attributed to a shift in consumer preference from chemicals and genetically modified crops to naturally sourced products. According to Rahman et al. [6], there is a further possibility of shifting the production in Northern Australia because of land availability and favourable climatic conditions, which we expect will enable two sesame growing seasons per year. Australia imports 90 per cent of sesame consumed. There is potential for import substitution and the development of export markets by producing sesame in the vast tropical and subtropical regions of Northern Australia. It is also expected that organic certification will be an important competitive advantage for Australia if sesame producers and/or exporters target the health and specialty segments of consumers.

For Australia to establish a viable sesame industry it should proactively consider the fact that sesame internationally is attacked by multiple pathogens and arthropod pests that require active management.

2. Disease Threats

Sesame diseases cause damage to seed, seedling, root, stem, as well as foliage resulting in significant loss [7]. Leaf spot, stem and leaf blotch, wilts, blight, charcoal rot, stem anthracnose, mildew, and phyllody are prominent diseases in sesame [8,9], from more than sixty-seven plant pathogens identified to cause diseases in sesame, globally [7,8,10–16] (Table 1). Sesame is prone to root rot and stem diseases associated with waterlogging, while damping-off diseases can also occur if humidity is high.

Table 1. Diseases of sesame reported globally.

Disease	Causal Pathogen	Countries Where Reported
	A. Fungi	
Charcoal rot/Dry root rot	*Macrophomina phaseolina*	Australia, Bangladesh, Brazil, China, Colombia, Cuba, Cyprus, Ecuador, Egypt, Ethiopia, Greece, Honduras, India, Iran, Iraq, Israel, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Sri Lanka, Sudan, Syria, Tanzania, Thailand, Turkey, Uganda, USA, and Venezuela [16]
Wilts	*Fusarium oxysporum* f. sp. *sesame/Fusarium* spp.	Australia, Bangladesh, Brazil, Bulgaria, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Egypt, Ethiopia, Greece, Guatemala, Honduras, India, Iran, Iraq, Israel, Italy, Japan, Kenya, Malawi, Mexico, Nicaragua, Nigeria, Pakistan, Paraguay, Philippines, Republic of Korea, Saudi Arabia, Sierra Leone, Sudan, Tanzania, Thailand, Turkey, Uganda, Ukraine, USA, Uzbekistan, and Venezuela [16]
	Verticillium spp.	Australia, Bulgaria, China, Egypt, Ethiopia, India, Pakistan, Turkey, Uganda, USA, and Uzbekistan [16]
	Neocosmospora spp.	Uzbekistan [16]
Root rot/Stem rot	*Rhizoctonia solani*	Australia, Bolivia, Brazil, China, Colombia, Costa Rica, Dominican Republic, Egypt, India, Iraq, Japan, Myanmar, Nicaragua, Pakistan, Panama, Republic of Korea, Uganda, USA, and Venezuela [16]
	Sclerotinia spp.	India, and Mexico [16]
	Phymatotrichopsis spp.	USA [16]
	Thielaviopsis spp.	Egypt and USA [16]
	Helicobasidium spp.	China [16]
	Gibberella spp.	India, Iran, Iraq, Nigeria, Pakistan, Republic of Korea, Sudan, and Uganda [16]
Root/stem/collar rot, southern blight	*Sclerotium rolfsii*	China, Costa Rica, Greece, Honduras, India, Italy, Japan, Mexico, Nicaragua, Nigeria, Philippines, Sudan, USA, and Venezuela [16]
Alternaria leaf spot/leaf blight	*Alternaria sesame/A. alternata/A. simsimi/Alternaria* spp.	Australia, Bolivia, Brazil, Burkina Faso, China, Costa Rica, Cuba, Egypt, Ethiopia, Greece, Guatemala, Honduras, India, Iran, Iraq, Israel, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Russia, Saudi Arabia, Sudan, Tanzania, Turkey, Uganda, Ukraine, USA, and Venezuela [16,17]

Table 1. *Cont.*

Disease	Causal Pathogen	Countries Where Reported
	A. Fungi	
Cercospora leaf spot	*Cercospora sesame*	Australia, Brazil, Burkina Faso, China, Colombia, Dominican Republic, Egypt, Ethiopia, Guatemala, Honduras, India, Israel, Italy, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Panama, Paraguay, Philippines, Somalia, Sri Lanka, Sudan, Surinam, Tanzania, Thailand, Turkey, Uganda, USA, and Venezuela [16]
Angular leaf spot	*Cercospora sesamicola*	Australia [18], India [19], Kenya [20]
Powdery mildew	*Oidium* spp.	Australia, China, Ethiopia, Greece, India, Israel, Japan, Mexico, Myanmar, Nigeria, Sri Lanka, Sudan, Tanzania, Uganda, USA, and Venezuela [16]
	Podosphaera xanthii (=*Sphaeroteca fuliginea*)	Australia, China, Ethiopia, India, Iraq, Japan, Malawi, Mexico, Somalia, Sudan, Tanzania, and Turkey [16]
	Leveillula taurica/Leveillula spp.	India, Italy, Japan, Mexico, Pakistan, USA, and Venezuela [16]
	Erysiphe cichoracearum (syn. *Golovinomyces cichoracearum*)/*Erysiphe orontii*/*Erysiphe* spp.	China, Ethiopia, India, Japan, Mexico, Sudan, Thailand, Republic of Korea, and Uganda [16]
	Podosphaera spp.	Australia, China, Ethiopia, India, Iraq, Japan, Malawi, Mexico, Somalia, Sudan, Tanzania, and Turkey [16]
Corynespora blight and target spot	*Corynespora cassiicola*	Australia, Brazil, China, Colombia, Costa Rica, Cuba, Ecuador, India, Japan, Mexico, Republic of Korea, USA, and Venezuela [16]
Brown angular spot	*Cylindrosporium sesame/Pseudocercospora sesami*	Australia, Ecuador, Mexico, Venezuela [16]
Aerial stem rot/Leaf spot	*Helminthosporium sesame/Helminthosporium* spp.	China, Costa Rica, Egypt, India, Italy, Japan, Kenya, Nigeria, Philippines, Saudi Arabia, Tanzania, and USA [16]
Leaf spots	*Ascochyta* spp.	China, Japan, and Sudan [16]
	Cladosporium spp.	Cuba, Egypt, India, Iran, Iraq, Nigeria, Pakistan, Saudi Arabia, and Venezuela
	Curvularia spp.	Bangladesh, Cuba, India, Nigeria, Pakistan, Paraguay, Saudi Arabia, and Sudan
	Colletotrichum spp.	China, India, Italy, Japan, Mexico, Myanmar, Nigeria, Paraguay, Republic of Korea, Thailand, Uganda, and USA [16]
	Drechslera spp.	Brazil, Egypt, India, Mexico, Pakistan, Saudi Arabia, and Sudan [16]
	Cercoseptoria spp.	India, USA, and Venezuela [16]
	Cochliobolus spp.	Cuba, India. and Nigeria [16]
	Gloeosporium spp.	Italy [16]
	Exserohilum spp.	Egypt and Saudi Arabia [16]

Table 1. *Cont.*

Disease	Causal Pathogen	Countries Where Reported
	A. Fungi	
	Phoma spp.	Brazil, China, Cuba, Egypt, India, Italy, Japan, Mexico, Nigeria, Philippines, Republic of Korea, Sudan, and Venezuela [16]
	Pseudocercosporella spp.	India and Turkey [16]
	Myrothecium spp.	Egypt and India [16]
	Paramyrothecium spp.	Cuba, India, and Pakistan [16]
	Pestalotiopsis spp.	Nigeria [16]
Stem blight	*Didymella* spp.	Cambodia, India, and Mexico [16]
Wet rot of seedlings	*Choanephora cucurbitarum*	India [16]
Leaf blight	*Nigrospora sphaerica*	China [21]; Egypt, and Pakistan [16]
Anthracnose	*Colletotrichum* spp.	China, India, Italy, Japan, Mexico, Myanmar, Nigeria, Paraguay, Republic of Korea, Thailand, Uganda, and USA [16]
	Sphaeronema spp.	India [16]
Rust/Warts	*Synchitrium* spp.	India and Mexico [16]
	B. Oomycetes	
Phytophthora blight	*Phytophthora* spp.	Argentina, China, Dominican Republic, Egypt, Guatemala, Honduras, India, Iran, Japan, Kenya, Malawi, Mexico, Nicaragua, Nigeria, Paraguay, Peru, Republic of Korea, Sri Lanka, Tanzania, Thailand, Turkey, USA, and Venezuela [16]; Australia [22]
Damping-off	*Pythium* spp.	Australia, Costa Rica, Egypt, India, Iraq, Kenya, Mexico, Pakistan, Republic of Korea, Thailand, USA, and Venezuela [16]
	C. Bacteria	
Bacterial leaf spot	*Pseudomonas* spp.	Australia, Brazil, Bulgaria, Burkina Faso, China, Cuba, Ethiopia, Greece, Guatemala, India, Japan, Kenya, Macedonia, Malawi, Mexico, Myanmar, Nigeria, Pakistan, Paraguay, Republic of Korea, Somalia, Sudan, Tanzania, Thailand, Turkey, USA, and Venezuela [16]
Bacterial blight	*Xanthomonas campestris* pv. *sesami*	Myanmar [8]; Brazil, Burkina Faso, China, Ecuador, Ethiopia, Honduras, India, Japan, Malawi, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Sudan, Turkey, USA, and Venezuela [16]
	Pseudomonas solanacearum = *Ralstonia solanacearum*	China, India, Iraq, Japan, Mexico, Republic of Korea, Thailand, and USA [16]
Bacterial wilt	*Erwinia* spp.	Ethiopia [16]

Table 1. *Cont.*

Disease	Causal Pathogen	Countries Where Reported
	A. Fungi	
Phyllody, Witches' broom	Phytoplasma	Myanmar [8]; Australia, Brazil, Burkina Faso, China, Egypt, Ethiopia, India, Iran, Iraq, Israel, Italy, Japan, Kenya, Malawi, Mexico, Myanmar, Niger, Nigeria, Oman, Pakistan, Paraguay, Philippines, Republic of Korea, Senegal, Sierra Leone, Sri Lanka, Sudan, Syria, Taiwan, Tanzania, Thailand, Turkey, Uganda, USA, Venezuela, and Vietnam [16]
Yellows	*Spiroplasma* spp.	Iran and Turkey [16]
Seed-borne disease	*Memnoniella* spp.	India [16]
	D. Viruses	
Mosaic	Cowpea Aphid-Borne Mosaic Virus (CABMV)	Ivory Coast, Mexico, Paraguay, and USA [16,23]
	Tobacco vein banding mosaic virus (TVBMV)	China [16,24]
	Watermelon Mosaic Virus (WMV)	China, Japan, and Republic of Korea [16]; Australia [25]
	Bean Common Mosaic Virus (BCMV)	China [16]
	Zucchini yellow mosaic virus (ZYMV)	China [16]
	Sesame yellow mosaic virus (YMo-I)	China [26]
	Turnip mosaic virus (TuMV)	China and Japan [16]
	Pepper mild mosaic virus (PMMoV)	China [16]
	Tobacco mosaic virus (TMV)	Nigeria [16]
Stripe	Peanut stripe virus (PSV)	China [16]
Leaf curl	Sesame curly top virus (SeCTV)	Iran [16]
	Tomato yellow leaf curl virus (TYLCV)	Nigeria [16]
	Tobacco leaf curl virus (TLCV)	China, India, Mexico, Myanmar, Pakistan, Nigeria, Sierra Leone, Sudan, Tanzania, and Venezuela [16]
Spotted wilt	Tomato spotted wilt virus (TSWV)	Mexico [16]
Yellow spot	Melon yellow spot virus (MYSV)	Mexico [16]
Bud necrosis	Groundnut bud necrosis virus (GBNV)	India [16]

In 1995, during the early attempt to establish an Australian sesame industry, Conde [27] reported that of the thirty-two or more diseases on sesame in the world, only nine are found in Australia. Seven of these occur in the Northern Territory, with only *Corynespora cassiicola* (target spot or leaf stem and pod spot) and *Pseudocercospora sesami* (large *Cercospora* leaf spot) of serious agronomic concern [28]. Bennett and Lang [29] also observed target spot, caused by *Corynespora cassiicola*, that could cause severe seed rot, seedling mortality, and root rot in sesame, in the Northern Territory. Matchett [30] investigated the pathogenicity of the soilborne fungi *Rhizoctonia solani, Verticillium dahliae*, and *Fusarium oxysporum* to sesame under a controlled environment experiment and found that these pathogens do not have significant effect on the yield of the crop. In 1996, the CSIRO and the Northern Territory Department of Primary Industry and Fisheries (NTDPIF) released a sesame cultivar out of the breeding efforts from sesame germplasm introductions from Japan, Mexico, Myanmar, Republic of Korea, and Venezuela with further breeding continued to improve seed retention and resistance to charcoal rot [31]. Bennett et al. [32] reported five sesame diseases observed in the Northern Territory: large *Cercospora* leaf spot, small *Cercospora* leaf spot, powdery mildew, charcoal rot, and phytoplasma little leaf.

Recent trials have revealed several potential disease issues, including wilt caused by *Sclerotium rolfsii* and leaf and pod spots caused by *Alternaria* sp., *Curvularia* sp., and *Phyllosticta* sp., as well as phytoplasma phyllody, and observations in southern Queensland during the summer of 2021 documented wilts from *Fusarium* sp., charcoal rot from *Macrophomina phaseolina*, leaf spot/blight from *Alternaria* spp., *Nigrospora* sp., *Phomopsis* sp., *Pestalotiopsis* sp., *Exserohilum* sp., and *Epicoccum* sp., along with seedling blight caused by *Sclerotium* sp. (D.L. Adorada, pers. obs.) Additionally, Harris et al. [33] reported the presence of large *Cercospora* leaf spot, small *Cercospora* leaf spot, target spot, powdery mildew, charcoal rot, and little leaf caused by mycoplasma found in the Gulf Rivers. Current work has revealed one or more of the preceding diseases in various trial locations in Northern Australia (Figure 1) (D.L. Adorada, pers. obs.). During winter in Australia, sesame can still be planted in the northern regions, where the climate is more tropical. So far, trials conducted in Northern Australia show that diseases have not significantly impacted sesame crops in terms of severity or incidence. However, if the sesame industry expands and crops become more concentrated in both time and space, there is a strong possibility that disease severity will increase. To mitigate this risk, it is essential to implement phytosanitary measures, practice crop rotation, and adopt other disease management strategies.

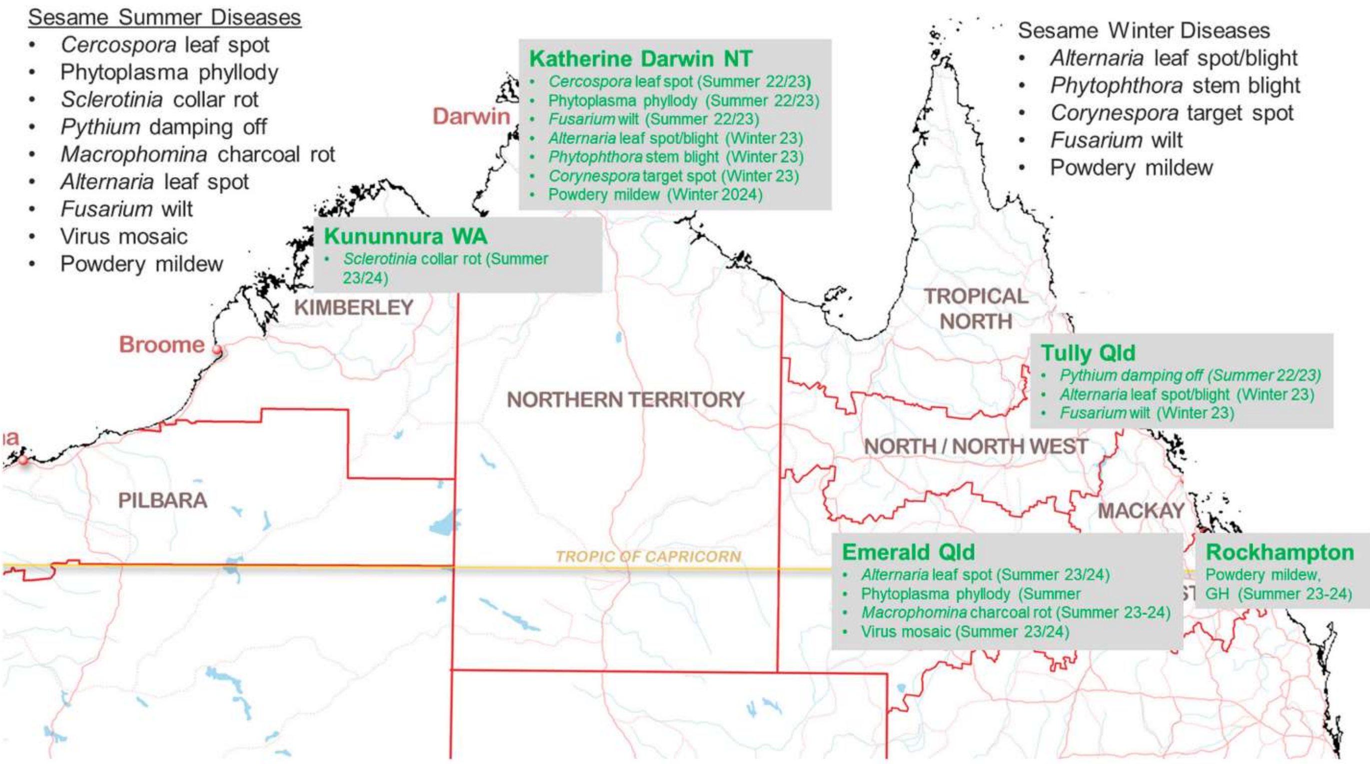

Figure 1. Sesame diseases identified from small plot trials and production plots in Northern Australia and Central Queensland.

3. Fungal and Oomycete Diseases

3.1. Fusarium Wilt

Fusarium wilt, caused by the fungus *Fusarium oxysporum* f. sp. *sesami,* is one of the most important diseases affecting sesame at all growth stages, starting from seedling to maturity, and causes the sudden death of plants, thus causing heavy economic losses depending on the severity of the infection [7,34]. This soilborne fungus is considered the most destructive disease of sesame worldwide [35]. The pathogen occurs throughout most sesame-growing areas worldwide causing vascular wilt (Figure 2), and sesame fields infected with *Fusarium* wilt disease exhibit conspicuous patches of dead plants [36–38]. Symptoms are the yellowing, drooping, and withering of leaves [36], with infected plants gradually withering, displaying wilting symptoms leading to drying, and eventually the infected portions of root and stem show long, dark black streaks of vascular necrosis. The fungus produces chlamydospores (resting spores) that are resistant to unfavourable environmental conditions, and it can survive on infected crop debris in the soil for about three to six years, with infection reoccurring from soil or seeds [39–41]. It is also seed-borne and primary infection occurs through infected seeds or through chlamydospores in soil, while secondary infection may be caused by conidia disseminated by rain splash and irrigation water [36]. *Fusarium oxysporum* is a ubiquitous plant pathogen and can be found everywhere in Australia, causing wilt disease in all crops planted. This pathogen may cause heavy yield losses of up to 100% [42].

Figure 2. Symptoms of wilt in sesame caused by *Fusarium oxysporum* f.sp. *sesami*. Image by: D.L. Adorada.

3.2. Charcoal Rot/Dry Root Rot

The disease is caused by the fungus *Macrophomina phaseolina* (Sclerotial stage: *Rhizoctonia bataticola*) [13,43]. The fungus attacks young seedlings, their stems become water soaked, soft, and are incapable of supporting the seedling which falls over and dies [14,36,44]. Disease symptoms start as the yellowing of lower leaves, followed by drooping and defoliation. The stem portion at ground level shows deep brown lesions, while the bark at the collar region shows shredding. On older seedlings elongated brownish black lesions appear that increase in length and width, girdling the stem, and kill the plant which shows a considerable number of black pycnidia (Figure 3). Infection to pods causes premature opening and immature shrivelled seeds that become black in colour. Pycnidia can also be seen on the infected capsules and seeds. Rotten root and stem tissues contain many minute black sclerotia and may also be present on the infected pods and seeds. The pathogen survives in seed and soil. High soil temperatures and moisture stress conditions favour the growth of the pathogen.

The disease is favoured by day temperatures of 30 °C and above, prolonged drought followed by an abundant supply of moisture [36]. The fungus remains dormant as sclerotia in soil as well as infected plant debris in soil. Infected plant debris carries pycnidia. The fungus is spread by infected seeds that carry sclerotia and pycnidia. It also spreads through soilborne sclerotia, while secondary spread is through conidia transmitted by wind and rainwater.

Figure 3. Charcoal rot symptoms on a stem of sesame. The stem near the ground with dark brown lesions and shredding of the bark, that later turns into black, dry rot that extends across the stem base. Image by: D.L. Adorada.

Among the important diseases of sesame, charcoal rot (CR) is considered the most destructive one and causes between 5 and 100% yield loss in all sesame growing areas [11,45,46]. A relationship between pathogen inoculum density in soil and disease intensity, and between disease intensity and yield loss, was found [47,48]. Hence, some agricultural practices have intended to reduce the inoculum density [44].

The disease was reported to be managed by fungicides, particularly carbendazim, thiram, mancozeb, and tebuconazole [36,44,49]. New fungicide chemistries were found effective in vitro but require an appropriate concentration to diminish disease losses [50]. Seed treatment with *Trichoderma viride* and before sowing mix in soil were found effective and economical for the management of this disease [36,51,52]. The antagonism activity of *Bacillus methylotrophicus* against *M. phaseolina* was determined by in vitro study, and it could be a biocontrol agent to prevent the damage of charcoal rot disease [53]. In vitro, soluble silicon was found effective in inhibiting mycelial growth of *M. phaseolina* from sesame [54]. Natural products have been shown as well to be safe and economical control of the disease in sesame [55,56]. Currently, none of these fungicides and/or biological control agents are registered for sesame use in Australia.

Traditionally, agricultural chemical prevention measures are used to reduce damage caused by *M. phaseolina*, but it has become more important to develop disease-resistant varieties [57]. So far, no resistance to charcoal rot has been reported in Australia. However, in other sesame growing countries several genotypes were found to have tolerance or resistance to the disease that can be used in breeding programmes. Through transcriptomics, the molecular mechanism of sesame resistance against *M. phaseolina* in disease-resistant and disease-susceptible sesame genotypes was understood [57–59].

Macrophomina phaseolina is necrotrophic and thermophilic in nature. Until recently, only one species was recognised, though it exhibited huge variability in morphology and pathogenicity has been seen among various isolates from different hosts [50]. More recent findings showed the presence of more than one species of *Macrophomina* present in Australia [60]. *Macrophomina pseudophaseolina* is reported for the first time in Australia, while *Macrophomina tecta* was isolated from sorghum and mungbean stems with charcoal rot symptoms in New South Wales and Queensland. This has implications for disease epidemiology and pathogen evolution, where two or more *Macrophomina* species have the potential to co-infect the same host. This warrant investigations into the distribution, biology, host range, and population diversity of the new recorded *Macrophomina* species.

3.3. Root/Stem Rot, Seedling Blight, and Damping-Off

Root/stem rot, seedling blight, and damping-off diseases are caused by *Rhizoctonia solani* and are among the problems in Australia [13]. At the seedling stage, it causes seedling blight and damping-off. Symptoms of root or stem rot include dark brown lesions on the stem just above the soil line, and plants having advanced symptoms exhibit necrosis progressing up the stem [61]. Stunting, late season lodging, and reduced yield were associated with areas of disease in approximately 5% of the total field.

A combination of strategies classified into the following was recommended by Lamichhane et al. [62] for the effective management of damping-off: (i) seed treatment to enhance germination and seedling vigour, (ii) deployment of resistant or tolerant cultivars to damping-off diseases, (iii) adoption of best cropping practices, i.e., crop rotation, integrated pest management, and diversifying crops, and (iv) timely treatment interventions of seedlings with effective products (conventional pesticides as well as biopesticides and/or biocontrol agents).

3.4. Collar Rot, Southern Blight, and Stem/Root Rot

The fungus *Sclerotium rolfsii* causes stem/root rot [13,63,64], collar rot [65], and southern blight [66,67] in sesame. Infected plants become yellow and then wilt; the collar root turns brown and rots and sclerotia are produced on the infected stem and on the soil surface [68]. The fungicide, Tilt 250EC (Propiconazole) was found most effective and completely inhibited the radial growth of *S. rolfsii* in vitro [64]. Praveenkumar [65] found that Nimbicidin, *Trichoderma harzianum*, and cow urine + vermiwash, and cow urine + butter milk were found effective in inhibiting mycelia growth and sclerotia formation of *S. rolfsii*, while against collar rot, vermicompost was found to be effective in minimising disease incidence.

3.5. Alternaria Leaf Spot, Alternaria Leaf Blight, and Stem Necrosis

Several species of *Alternaria* have been reported to cause disease in sesame: Alternaria leaf spot is caused by *Alternaria sesami* [13,69–74] and *A. simsimi* [75]; *Alternaria* leaf blight is caused by *A. alternata* [76] (Figure 4). The pathogen attacks all parts of the plant at all stages [13,36] with symptoms that include small, dark brown water-soaked, round to irregular lesions, with concentric rings, 1–8 mm in diameter appearing on the leaves, and under excessive atmospheric and soil humidity the spot increases in size and number. The lesions could also appear on the midrib and veins of the leaves. Milder attacks cause only defoliation, but in severe cases the plant may die. Temperatures of 20–30 °C, cloudy weather and high humid conditions favour the disease. Plants were observed to be most susceptible at 8–10 weeks' age [70]. The fungus is seed-borne and soilborne as it remains dormant in the infected plant debris. Contaminated seeds could pose a problem in the introduction of *Alternaria* leaf spots to areas new to sesame production, as it can be spread by infected seeds [77]. *Alternaria* species have a wide host range [78], and *A. sesami* could already be present in the field in small numbers until changes in the environment or farming practices favour disease development, thus posing a problem.

Yu et al. [79] detected *A. sesami*, *A. sesamicola*, *A. tenuis* (*A. alternata*), and *A. longissima* in Korean seed samples of *Sesamum indicum*. *A. sesamicola* was the predominant species from seed infection in the samples. Generally regarded as a saprophyte, *A. longissima* was for the first time found to be pathogenic, producing zonate leaf spots, foliage blight, stem necrosis and spots on sesame capsules. *A. sesami* and *A. sesamicola* caused severe symptoms and affected seed germination and seedling stand.

Figure 4. Leaf blight symptoms caused by *Alternaria alternata*, characterised by distinctive spots on leaves, stems, and capsules. These spots develop a yellow halo and eventually merge, causing larger necrotic areas leading to defoliation. Image by: D.L. Adorada.

Alternaria leaf blight (*Alternaria alternata)* in sesame may cause significant yield losses, with reductions in plant health and seed quality, as demonstrated by Nayyar et al. [76] from the fields in Punjab, Pakistan. This *Alternaria* species caused a decline in sesame production in India causing yield loss up to 30–40% [69]. In Korea, leaf spot on sesame was identified to be caused by *Alternaria simsimi* [75].

Management includes seed treatment with Thiram or Carbendazim and Mancozeb or Iprodion spray [36], spraying with Propiconazole or Difenoconazole [80]. However, resistant varieties are the best option for managing *Alternaria* blight and some resistant sources have been reported by Marri et al. and Rajpurohit and Solanki [81]. Investigations by Tozlu et al. [82] indicated that *Bacillus subtilis*, *B. pumilus*, *B. megaterium*, and *Trichoderma harzianum* are effective in vitro and should be tested against *A. alternata* in field condition. Roco and Perez [83] have demonstrated that the in vitro biocontrol ability of *T. harzianum* on *Alternaria alternata* could improve in the presence of the growth regulators gibberellic acid (GA3), or indoleacetic acid (IAA) or benzyl aminopurine (BAP) or foliar nutrient at concentrations similar or higher than those used at the field level. Natural plant extracts/products of peppermint, lavandula, eucalyptus, datura, nettle [84], *Senna alata* [85], and neem [86] have also shown potential as safe alternatives for chemical fungicides in managing *Alternaria* leaf spot in sesame.

A. alternata is the only species identified in Australia, affecting sesame from Northern Australia to Southern Queensland (D.L. Adorada, unpublished).

3.6. *Cercospora* Leaf Spot

This disease is caused by the fungus *Cercospora sesami* Zimm and is one of the most economically important diseases of sesame in almost all the production areas [13,87]. It affects sesame at all growth stages and infects all above ground parts of the plant, resulting in complete defoliation which leads to severe economic losses [88]. The disease, which affects leaves as early as four weeks after planting, starts as small pinhead-sized cottony spots on the infected leaves. Spots gradually spread on the lamina and can extend up to irregular spots of 5–15 mm diameter on both the leaf surface, and extensive infection leads to defoliation and damage of capsules before the plant reaches maturity which can result in yield losses of 20 to 50% [36,89]. The fungus is externally and internally seedborne [89] and can also survive in plant debris. Primary infection may be from seeds and infected debris, while secondary spread is through wind-borne conidia. The fungal spores are spread to healthy plants through rain, irrigation water, and wind. Germination occurs in humid conditions, usually during late spring and summer, and fungus growth is encouraged when leaves are frequently damp [90]. Management includes seed treatment with Carbendazim or Thiram, and spray with Mancozeb. Teshome, and Kora [91] demonstrated the effectiveness of propiconazole for the management of *Cercospora* leaf spot disease on sesame at both small-scale and large-scale production level. Due to lack of resistance sources, available cultivars are highly susceptible [7]. Extensive infection of foliage and capsule leads to defoliation and damage of sesame capsules, and yield losses may range from 22 to 53% [92]. Biological control using *Trichoderma viride*, in combination with vermicompost and fungicides, was found effective in reducing disease incidence, thus improving yield [93].

Cercospora leaf spot of sesame, caused by *Cercospora sesami*, was first observed in Australia in 1996 [18]. The disease is currently observed in the Northern Territory and Queensland (Figure 5) (D.L. Adorada, pers. obs.)

Figure 5. *Cercospora* leaf spot observed at: (L–R) Katherine Research Station, Darwin Northern Territory; Bundaberg, Queensland; and Gurgeena, Queensland. Image by C. Kelly and D. L. Adorada.

3.7. Angular Leaf Spot/Brown Angular Spot

The disease is caused by the fungus *Cylindrosporium sesame* [8,13] synonyms: *Cercoseptoria sesami*, *Cercospora sesamicola,* and *Pseudocercospora sesami* [94]. It is a destructive fungal pathogen that causes angular leaf spot in sesame, infecting all parts of the plant from seedling to physiological maturity leading to seedborne and further serving as a primary source of inoculum for the next season [93]. The disease appears as small, angular brown leaf spots of 3 mm diameter with a grey centre and dark margin bounded by veins [87,93]. In severe cases defoliation occurs. With favourable conditions, the disease spreads to leaf petiole, stem, and capsules producing linear dark-coloured deep-seated lesions. So far, only *Pseudocercopora sesame*, causing angular leaf spot in sesame, was reported to be present in Australia [18].

3.8. Powdery Mildews

Various fungal species have been reported to cause powdery mildew in sesame, namely: *Erysiphe cichoracearum* [95], *E. orontii* [96], *Leveillula taurica* [97], *Oidium* sp. ([98], *O. erysiphoides* [13], *O. sesami* [99], *O. mirabilifolii* [100]), and *Sphaerotheca fuliginea* [101]. All these fungal species are morphologically similar. Hence, an attempt was made to characterise the pathogen using ITS sequences developed by [102]. Cross-infectivity studies have shown that there was no infection of the powdery mildew pathogen from sesame on sunflower and vice versa [103]. Powdery mildews cause yield losses ranging from 25 to 50% depending upon the level of incidence, with an average yield loss of 45% reported by Egonyu et al. [104], in Uganda.

Powdery mildew infection caused by the fungus *Oidium erysiphoides* [13] can start from seedling stage up to mature plants [105]. All parts of the sesame plant *viz*., leaves, stems, flower buds, and pods were found to be affected by this fungus. The most susceptible tissue to fungal attacks is the leaves. Symptoms start as small whitish spots on the upper surface of the leaves at the age of forty days or more (Figure 6). The lower leaves developed infection first, and from these the infection spread to the other leaves and finally to other parts of the plant. Depending on the favourable conditions, the disease spreads to both the surfaces of lower leaves and lower surface of upper leaves, which coalesce to form larger spots to cover the entire leaf with dirty white fungal growth. Symptoms include necrosis of the leaf surface, premature leaf fall, stunted plant growth at the early stage, chlorosis of the leaf at the mature stage and browning of flower buds [105]. Then, severely infected leaves drop off, leaving a bare stem. This results in shrivelled seeds and reduced yield.

Figure 6. Powdery mildew disease on sesame from a glasshouse experiment at UniSQ Toowoomba, Queensland, Australia. Image by: D.L. Adorada.

Another species of fungus causing powdery mildew in sesame in India is *Podosphaera xanthii* (syn. *Sphaeroteca fuliginea*) [103]. It occurs on epidemic scale during flowering and post-flowering stages under favourable weather conditions of high humidity and low night temperature. Among the biotic stresses, powdery mildew is one of the economically important diseases that decrease sesame yields significantly from 25 to 50 per cent depending upon the level of severity [105].

The host organ most affected by the powdery mildew fungus *Leveillula taurica* is the leaf blade [106]. Petioles, stalks, and flowers are rarely affected, and fruits are only occasionally infected. The fungus penetrates the interior leaf tissues and symptoms are usually apparent on the ventral side as powdery, whitish spots that gradually expand, while on the dorsal side, yellow spots with varying intensity develop opposite the spotted ventral side, where powdery spots may also develop. Pale yellow spots may later become necrotic.

Powdery mildew caused by *Erysiphe cichoracearum* starts as greyish-white powdery growth on the upper surface of leaves [36]. When several spots coalesce, the entire leaf surface may be covered with powdery coating, and in extreme cases, the infection may be seen on the flowers and young capsules, which leads to premature shedding. Severely affected leaves may be twisted and malformed. At the advanced stages of infection, the mycelial growth changes to being dark or black because of cleistothecia formation. The fungus is an obligate parasite and survives through cleistothecia in the infected plant debris in the soil. The ascospores from the cleistothecia cause primary infection, while the secondary spread is through wind-borne conidia. The disease is favoured by dry humid weather and low relative humidity and can be managed by eradicating/eliminating infected plant debris and spraying wettable sulphur or karathane.

There have been several detections of powdery mildew of sesame in Australia; however, the only powdery mildew species characterised was *Golovinomyces* sp., found in Southern Queensland (D.L. Adorada, pers. obs., 2023–2025).

3.9. Corynespora Blight/Target Spot

Corynespora leaf spot (CLS) caused by the fungus *Corynespora cassiicola* is one of the most severe diseases in sesame, and *C. cassiicola* can survive in soil for at least two years [107]. *C. cassiicola* has many hosts and mainly invades host tissues through spore germination, subsequently causing the necrosis of the infected parts of the host plants [108]. A sesame cultivar with immunity to CLS is yet to be found. It is a necrotrophic fungus [109] that destroys its hosts to utilise its nutrients, overwinters on infected debris and seeds [110]. Chlamydospore formation of *C. cassiicola* isolates allows the pathogen to survive in soil or plant debris in unfavourable conditions or in the absence of the host [111], which serves as well as a source of primary inoculum [110].

The most characteristic symptom of *C. cassiicola* is the target-shaped lesion where large spots are often distinctly zonate with a darker spot in the centre of the lesion [112] (Figure 7). Often, leaf symptoms can be associated with a dull-green or yellowish-green halo with a typical 'target spot' in the centre. Leaf veins, petioles, and stems exhibit dark brown lesions with different shapes and sizes; lesions on pods are usually circular, depressed, and dark in the centre with brown margins [112,113]. Premature defoliation occurs in severe cases of infection under optimum conditions, while the lower canopy with higher humidity and proximity to the soil-borne primary inoculum tends to offer optimum conditions for pathogen infection and disease development [113]. It also causes root rot as reported by Gao et al. [114]. *Corynespora cassiicola* has been reported in Australia, however, affecting hosts other than sesame, such as papaya [115].

Figure 7. Symptoms of *Corynespora cassiicola* target spot and stem rot in artificially inoculated sesame, respectively. Image by: D.L. Adorada.

3.10. Anthracnose

Anthracnose in sesame is caused by *Colletotrichum* sp. [12,13,36], with disease symptoms of dark brown lesions surrounded with yellow halo. The spots darken and expand as they age, covering a larger area of the leaves, then black acervuli develop in the middle portion on leaf stem and capsules. It thrives under moist, warm conditions, and is spread through watering, wind, rain, insects, or garden tools [116]. It is considered a minor disease of sesame and not yet reported in Australia.

3.11. *Bipolaris* Leaf Spot

Leaf spot on sesame caused by *Bipolaris sorokiniana* shows symptoms of small brown to purple lesions which expanded with time to distinct lesions or patches with reddish brown colour that girdle the leaf blade giving the plant turf an overall purple cast and leaves eventually withered, with a dry tan, to a light colour [117]. Little work has been reported on this pathogen in sesame; however, it has been isolated from diseased samples from surveillance in Australia (D.L. Adorada, pers. obs.).

3.12. *Helminthosporium* Leaf Spot, *Helminthosporium* Blight or Brown Leaf Spot, Aerial Stem Rot

These diseases are caused by *Helminthosporium sesame* [12,13,118]. Symptoms of the disease are small and circular dark brown or purple-brown spots eventually becoming oval brown spot with a grey to whitish centre [118]. The spots also appear on the stems, necks of the leaves and capsules and up to the seeds, which leads to a shortage of seed yield and reduced quality of oil produced. The infected seeds become a source of infection in the following season when used as a seed [119]. The disease has yet to be reported in Australia.

3.13. *Ascochyta* Blight/Leaf Spot

This disease is caused by *Aschochyta sesami* [13,120]. Symptoms are sometimes confused with *Alternaria* leaf spot and *Cercospora* leaf spot. *Ascochyta* blight symptoms are elongated lesions on stems, and circular lesions on leaves and pods [121]. Pycnidia, structures that produce infective spores, are circularly arranged on both stem and leaf, affecting seed size and quality. The disease has a specific strain for each crop host and cannot be spread between them [120]. *Ascochyta* spp. survive between seasons when infected seed is sown, or from infected stubble, where it can survive for several years. Development of the disease can occur at any plant growth stage and is favoured by cool, wet conditions.

Management of *Ascochyta* requires an integrated approach using cultural methods and registered fungicides. Recommended practices to manage risk of *Ascochyta* are as follows: crop rotation that allow spores on the soil or crop residue to lose viability; breaking disease cycle by fallowing; destroy infested trash residue, taking care to minimise wind erosion risks; use disease-free seed; control alternative hosts; plant more resistant/tolerant varieties; use a registered seed treatment; inspect regularly to identify disease symptoms early; and apply foliar fungicides in areas of high risk [120,122]. *Ascochyta* can easily be spread by spore transfer via clothing, people, machinery, vehicles, and animals; therefore, if it is detected, ensure all machinery and clothing is washed, disinfected, and removed from soil material before inspecting other crops. This disease has not been reported yet in Australia.

3.14. *Cladosporium* Leaf Spot

Cladosporium leaf spot, caused by *Cladosporium* sp. is characterised by round, tan leaf spots that normally do not exceed 0.25 inch in diameter, with dark green spores and mycelium developing in the centres of these spots at a later stage [123]. The presence of dark green sporulation distinguishes *Cladosporium* leaf spot from anthracnose and *Stemphylium* leaf spot diseases, both of which also form circular lesions. Treatment is rarely necessary. If used, copper sprays must be applied as protectants. This pathogen is seedborne, and several species have been identified that affect seed germination: *Cladosporium cladosporioides*, *C. herbarum*, *C. fulvum*, and *C. chlorocephalum* [124]. Although a common contaminant, it is yet to be confirmed as a sesame disease-causing pathogen in Australia.

3.15. Wet Rot of Seedlings

The disease is caused by *Choanephora cucurbitarum* [13,125]. *C. cucurbitarum* mostly attacks tissues that have been damaged by insects or mechanical means, or crops that are poorly adapted to a hot humid climate, causing stem and leaf rot [126]. The disease is favoured by wet weather, high temperature, and high humidity, from inoculum that is typically soil-borne. Signs of infection on leaves include water-soaked, necrotic lesions, which progress rapidly under ideal conditions. Once the fungus begins to produce spores, affected tissues become hairy and dark grey, brown because of the superficial sporangia. This disease has not yet been documented in Australia; however, it can affect sesame seedlings in Australia, particularly in warm, humid conditions [127].

3.16. Phytophthora Blight

The disease is caused by the Oomycete *Phytophthora parasitica* var. *sesami* [13,128], that can occur at all growth stages of the plant. The initial symptom is water-soaked spots on leaves and stems [14,89,129]. The spots are chestnut brown in the beginning which later turn to black that appear on the stem near the soil level. Premature leaf fall occurs. Infection may also be seen on flowers and capsules. In humid weather, the severity of disease increases, the main root is affected, diseased plants are easily pulled out and produce shrivelled seeds and give a blighted appearance. The fungus survives in soil, and high soil moisture favours the development of the pathogen. It is severe in heavy soil with high rainfall, low temperature (25 °C), and high relative humidity (above 90 per cent).

The pathogen can survive in the soil as dormant mycelium and oospores. Seeds can also carry the fungus as dormant mycelium, which serves as the primary inoculum, while secondary spread of the disease is through windborne sporangia [36]. Management is through seed treatment with Captan or Thiram, avoiding continuous cropping of sesamum in the same paddock, metalaxyl spray, and eradication and elimination of infected plant debris. Sharma et al. [128] demonstrated that metalaxyl + mancozeb spray significantly reduced the incidence of this disease. In India, field resistance to *Phytophthora* blight disease was reported on a black sesame variety that can be recommended in areas where the disease appears in severe form, and at the same time for use in hybridisation programmes to develop improved plant types [129]. The disease was seen as posing risks to sesame in Australia, especially during early establishment phases [22].

3.17. Damping Off

Damping off is a disease that leads to the decay of germinating seeds and young seedlings, which represents for farmers one of the most important yield constraints both in nurseries and fields [62]. The disease can be caused by several biotic or abiotic stresses/factors, which prevent seeds from germinating or seedlings to emerge. The Oomycetes, *Pythium* species, i.e., *Pythium aphanidermatum* and *Pythium ultimum* are soil inhabitants which exist and thrive in most agricultural soils for extended periods of time, especially if the soil is wet [130]. It is one of the soilborne organisms that causes damping off, and is easily spread by water flow from irrigation, flooding, and movement of soil by tractors and equipment. It can occur during every crop stage throughout the entire vegetation season. The first signs of this pathogen occur in the crop's root system and often no visible signs of pest attack on leaves are shown until significant injury and/or death occur. Symptoms of *Pythium* species infection are chlorosis of the lower leaves and stunting is the most recognisable above ground symptom; infected roots are soft, mushy, and appear in various shades of brown. The outer covering of the root, the cortex, is usually rotted and slides off easily when pulled, leaving the string-like vascular bundles behind. This is commonly referred to as "sloughing of the roots". Plants under stress due to high soluble salt concentrations, poor soil drainage, over-watering and various root injuries are particularly susceptible to *Pythium* infestations. This disease has been observed in sesame trial establishments in Australia.

4. Bacterial and Phytoplasma Diseases

4.1. Bacterial Blight

The disease is caused by the bacterium *Xanthomonas campestris* pv. *sesami* [131] affecting plants at all age and causing seed infection, which is a major cause for dispersal of the disease [132]. Symptoms include water-soaked spots that appear initially on the undersurface of the leaf and then on the upper surface. The size increases, becoming angular and restricted by veins and deep brown in colour. When several spots coalesce together it forms irregular brown patches and causes drying of leaves. On petioles and stem, reddish brown lesions may also occur.

Xanthomonas campestris pv. *sesami* is a Gram-negative rod bacterium with a monotrichous flagellum, which survives in the infected debris and in seeds. Secondary spread is by rain splashes. Suggested management strategies are removal and burning infected plant debris, and spray with Streptomycin sulphate or oxytetracycline hydrochloride or streptocycline [89].

4.2. Bacterial Leaf Spot

The disease is caused by *Pseudomonas sesami* [13] or *Pseudomonas syringae* pv. *sesami* [133], a Gram-negative aerobic bacterium with one or more polar flagella [89]. Disease symptoms appear as water-soaked yellow specks on the upper surface of the leaves, which enlarge and become angular as restricted by veins and veinlets. Spot colour may be deep brown with shiny oozes of bacterial masses. The bacterium remains viable in the infected plant tissues and is internally seedborne with secondary spread attained through rain splash and storms.

Suggested management strategies are keeping the field free of infected plant debris and spraying with Streptomycin sulphate or oxytetracycline hydrochloride or streptocycline [89]. Preliminary seed treatment with both physical and chemical methods for efficient control of sesame bacterial leaf spot in the laboratory indicated that hot water treatment or soaking in streptomycin reduced disease and increased seed germination, while foliar sprays showed that bactericide and antibiotic treatments could reduce the disease incidence [134].

So far, both the bacterial blight and bacterial leaf spot diseases caused by *Xanthomonas* and *Pseudomonas* infections, respectively, have not yet been documented in Australian sesame.

4.3. Phyllody

The disease is caused by a phytoplasma [13,135], a phloem-limited pleomorphic bacteria lacking the cell wall, mainly transmitted through leafhoppers but also by plant propagation materials [136]. Symptoms start with all floral parts transformed into green leafy structures followed by abundant vein clearing in different flower parts. The entire inflorescences are replaced by short, twisted leaves closely arranged on a stem with short internodes; abundant abnormal branches bend down, when the infection is severe [7]. Finally, plants will look like witches' broom (Figure 8), and if capsules are formed on the lower portion of the plant, they do not yield quality seeds, causing crop losses as high as 90 per cent [137]. The disease is transmitted through jassids and the phytoplasma survives in leafhoppers throughout its life.

Figure 8. Symptoms of phyllody or "witches' broom" caused by phytoplasma, collected from a sesame trap crop plot trial in Brigalow, southeast Qld. Image by: D.L. Adorada.

The pathogen *Candidatus* Phytoplasma [138] has a wide host range and survives on alternate hosts like rapeseed, turnip mustard, chickpea, rattlepods, white clover, and peanut/groundnut, which serve as a source of inoculum [89]. It is transmitted by *Orosius* spp., a planthopper present in Australia, and by other planthoppers and spittle bugs but knowledge of phytoplasma–vector systems is still expanding rapidly since the advent of molecular tools for the detection of these unculturable plant pathogens. Phytoplasmas have an incubation period in leafhoppers ranging between 15 and 63 days and 13 to 61 days in sesame. However, nymphs are incapable of transmitting the phytoplasma. Vector populations are higher during summer than in winter months. Wilson et al. [139] reported that the sweet potato little leaf variant Vinca 4 in the semi-arid tropics of Australia's Northern Territory, the most prevalent phytoplasma, was associated with symptoms of little leaf, or little leaf and phyllody, in all hosts (crop and non-crop species) except sesame, where it was most often associated with floral dieback.

The disease can be managed by removal of all reservoirs and weed hosts (sanitation); avoiding growing sesamum near cotton, ground nut and grain legumes; rogueing out infected plants periodically; spraying Monocrotopos or Dimethoate to control the jassids, and soil treatment with Thirmet or Phorate at the time of sowing [89]. In addition to common cultural, mechanical, and biological practices, intercropping of Sesame + redgram and spraying of neem oil for vector (leafhopper) control is helpful in managing the phyllody [7]. India's tolerant varieties are TKG 21, RT-125, and RT-103. The phyllody disease is commonly observed on sesame in areas where summer crops are grown in Australia (DL Adorada, pers. obs.).

4.4. Virus Diseases

To date, no viral disease has been observed or reported on sesame in Australia. However, as the industry expands from the north to the south of Australia, other diseases are anticipated to emerge.

4.5. Pest Threats

4.5.1. International Situation

An important limitation on achieving high yields with sesame in Australia is the extent to which it is attacked by native insect pests or exotic species that have become established in Australia. Globally, 210 species of insect pests have been recorded on sesame, with the Cicadellidae, Pentotomidae (Hemiptera), and Noctuidae (Lepidoptera) containing the largest numbers of pest species [140]. Ineffective management of pest insects has been considered a primary reason for low sesame yields in India [141], and in recent times, yields of sesame still vary considerably with highly productive countries such as China achieving yields 3–4 times that of less productive ones such as India (one of the world's top sesame producers) and Sudan [142].

The most prevalent and destructive of the Lepidoptera pests is the sesame webworm *Antigastra catalaunalis* Duponchel (Crambidae), recorded as one of the most (if not the most) destructive sesame pests in India, Nigeria, Ethiopia, and Uganda—with a recent arrival of this pest on sesame in Greece [104,141,143–145]. Other significant defoliating Lepidoptera include *Spilosoma* (syn. *Spilarctica*) *obliqua* (Walker), *Acherontia lachesis* (Fabricius), and *A. styx* (Westwood) [140,141,146]; however, these species are not currently found in Australia (GBIF, Atlas of Living Australia, accessed 25th November 2024). Although sesame can be attacked by the globally prevalent pest *Helicoverpa armigera* (Hübner), it causes low levels of damage [147]. Another commonly reported pest internationally is the sesame gall midge (*Asphondylia sesami* Felt) [104,141,148] which is not found in Australia, although other members of this cosmopolitan genus are (Atlas of Living Australia, accessed 25 November 2024). Kinati [143] reported termites as a significant pest in Ethiopia, though the species' identity was not reported. According to Kinati [141], chewing pests such as *Antigastra* were more prevalent in drier or average rainfall years, with wetter years tending to see more sucking pests instead. Globally, these Hemiptera include a variety of mirids, shield bugs, aphids, whiteflies and cicadas, with the most prominent including *Nesidiocoris* (syn. *Cyrtopeltis*) *tenuis* Reuter, *Orosius albicinctus* Distant, *Bemisia tabaci* Gennadius (cryptic species not specified), *Aphis gossypi* Glover, *Myzus persicae* Sulzer, *Nezara viridula* L., and *Elasmolomus pallens* Dallas (syn. *sordidus*) [140,141,143,146,149,150]. All of these except *O. albicinctus* occur in Australia (GBIF, Atlas of Living Australia, accessed 25 November 2024). Depending on location and time of year, different subsets of these pests can become the major pests on a particular crop of sesame (e.g., compare Biswas et al. [149] with Thangjam and Vastrad [146]). After harvesting, stored sesame seed is attacked by grain pests. These are beyond the scope of the present review but include the beetles *Tribolium castaneum* Herbst, *T. confusum* Jacquelin du Val, *Rhyzopertha dominica* Fabricius, and *Sitophilus oryzae* L., and the Indian meal moth *Plodia interpunctella* Hübner [151] all of which occur in Australia (GBIF, Atlas of Living Australia, accessed 25 November 2024).

Control of sesame pests internationally has a strong emphasis on the use of insecticide sprays such as imidacloprid, acetamiprid, thiamethoxam or lambda cyhalothrin, which can reduce levels of most pests by 75–100% [144,152]. Endosulfan is another pesticide which was shown to be effective against *A. catalaualis* [153]. Using neem seed extract as a pesticide in combination with imidacloprid seems to have the potential to increase effectiveness of pest suppression [154]. However, in the case of lambdacyhalothrin, *M. persicae* seems to be especially prone to resistance and population resurgence in response to spraying [144].

4.5.2. Sesame Pest Threats in Australia

When the extensive list of sesame pest insects worldwide [140] is filtered to exclude species not currently present in Australia (using GBIF.org and Atlas of Living Australia) and expanded to include additional species reported from Australia as listed by Langham [155], a list is generated of 56 taxa (Table 2). This comprises forty-seven species plus nine genera that have representative species in Australia, but which are in the Dilipsundar et al. [140] list as genera rather than having specific epithets. Accordingly, for taxa listed in Table 2 as 'genus sp.' it is possible that an Australian member of the genus will attack sesame though there is no direct evidence from overseas.

Table 2. A list of sesame pest taxa likely to affect sesame crops in Australia. Pest status categories: Actual = observed in trials 2024–2025, Possible Major = in the 'top 9' of Langham [155] the published literature and personal observations of the present authors (see text for detail).

Family	Species	Global Significance to Sesame	Status in Australian Sesame
Lepidoptera			
Crambidae	*Antigastra catalaunalis*	Major pest of foliage and pods in Africa, India, and SE Asia	Actual and Possible Major
	Maruca vitrata	Minor pest of pods in Uganda	
Noctuidae	*Agrotis ipsilon*	Destructive but sporadic foliage and stem pest	Possible Major
	Argyrogramma signata	Foliage pest India	
	Chrysodeixis acuta	Foliage pest Nigeria	
	Helicoverpa armigera	Global generalist pest, foliage and pods	Actual (scarce)
	Helicoverpa punctigera	Australian endemic, foliage and pods	Actual (scarce)
	Spodoptera exigua	Global generalist pests, minor foliage pests on sesame in India, Turkey, US, and Japan	Actual (scarce)
	Spodoptera littoralis		
	Spodoptera litura		
	Spodoptera frugiperda		
	Thysanoplusia orichalcea	Foliage pest, India, Bangladesh	
Hemiptera			
Aleyrodidae	*Bemisia tabaci* (or *B. argentifolii*)	Major foliage pest in India, Africa, and South America	Actual and Possible Major
Alydidae	*Leptocorisa acuta*	Pod pest, Bangladesh	
Aphididae	*Aphis craccivora*	Foliage pest, South America	
	Aphis gossypii	Foliage pest, reported major pest in India, minor pest elsewhere	
	Myzus persicae	Major foliage pest India, China, Africa, South America	Actual and Possible Major
Cicadellidae	*Amrasca biguttula*	Minor foliage pest, India	
	Balclutha incisa	Minor foliage pest, India	
	Batracomorphus angustatus	Foliage pest India	
	Cicadulina bipunctata	Foliage pest Turkey	
	Cofana spectra	Foliage pest Bangladesh	
	Deltocephalus sp.	Foliage pest and phyllody vector, Africa, and Asia	Possible Major #
	Exitianus sp.	Foliage pest, India	

Table 2. *Cont.*

Family	Species	Global Significance to Sesame	Status in Australian Sesame
	Orosius orientalis	Foliage pest and phyllody vector, India, Japan, Middle East	Possible Major #
Cixiidae	*Oliarus* sp.	Foliage pest, India	
Delphacidae	*Cemus* sp.	Foliage and pod pest, India	
Lyaeidae	*Elasmolomus pallens (sordidus)*	Pod pest, Africa, India, and Bangladesh	
	Nysius vinitor	Australian endemic	Actual (pods)
Miridae	*Campylomma* spp.	Foliage pest, India	
	Creontiades dilutus	Australian endemic	Actual (foliage, pods)
	Nesidiocoris tenuis	Australian endemic	Actual (foliage, pods)
	Poppiocapsidea biseratense	Foliage pest (minor), India	
	Taylorilygus sp.	Foliage	
Pentatomidae	*Chinavia hilaris*	Pods	
	Nezara viridula	Pods	Actual and Possible Major
	Plautia affinis	Australian endemic	Actual
Pseucoccidae	*Phenacoccus solenopsis*	Global generalist pest, pest on sesame in Pakistan, Ethiopia	
Pyrrhocoridae	*Dysdercus cingulatus*	Minor pod pest Bangladesh	
Tingidae	*Telenonemia scrupulosa*	Incidental foliage pest, East Africa *	
Thripidae	*Frankliniella occidentalis*	Flower pest, Turkey, USA	
	Frankliniella schultzei	Flower pest, Bangladesh	
	Scirtothrips dorsalis	Foliage pest, India	
	Thrips hawaiiensis	Foliage pest, India	
	Thrips palmi	Flower pest, India, Cuba	
	Thrips tabaci	Foliage pest, India, Nigeria	
Orthoptera			
Acrididae	*Gastrimargus musicus*	Australian endemics, observed 1970–1980s, foliage feeders	Actual
	Austracris guttulosa		Actual
Hymenoptera			
Formicidae	*Pheidole ampla*	Australian endemic, observed 1980–1990s, seed harvester ant	Actual
Coleoptera			
Cerambycidae	*Oberea* sp.	Stem pest, India	
Chrysomelidae	*Aulocophora* sp.	Foliage pest, India	
	Monolepta signata	Foliage pest, Bangladesh	
Diptera			
Psilidae	*Chyliza* sp.	Stem pest, India	

Langham [147] included these leafhoppers as a single category in the 'top 9' for their capacity to transmit phytoplasmas rather than direct feeding damage. * Habeck et al. [156] in EENY-246/IN514: Lantana Lace Bug, *Teleonemia scrupulosa* Stål (Insecta: Hemiptera: Tingidae).

4.5.3. Management Options for Sesame Pests in Australia

Insecticides are widely used for the management of sesame pests internationally but there are challenges to simply mirroring this approach in Australia, especially because the range of insecticides available is currently small and likely to increase only slowly. In Australia, the registration and use of insecticides is regulated by the Australian Pesticides and Veterinary Medicines Authority (APVMA), and a general principal is that applications to a given crop to control a given pest species is not permitted unless specified on the pesticide product label. At the present time (April 2025), there are only two insecticides registered for use in sesame crops in Australia: (i) methomyl (an oximes-carbamates sold as several products) and (ii) nuclear polyhedrosis virus (a biological virus). Importantly, however, the range of pests for which use is permitted is limited. Methomyl is registered for use only against cornworm (*H. armigera*) and green vegetable bug (*N. viridula*), whilst nucleopolyhedrovirus is registered only for *Helicoverpa* species. Accordingly, their relevance to combating other potentially serious pests, such as sesame leaf-roller is confined to circumstances where it is incidentally present in addition to one of the previously mentioned pests which are the intended (and legally permitted) target of the insecticide application.

The APVMA can, additionally, issue permits for off-label use which allow the use of certain insecticides in crops where full registration is not in place, often due to the crop's limited scale or specific pest challenges. Two additional insecticides are covered by such permits. The carbamate insecticide pirimicarb is permitted for use in Australian sesame until October 2026 against aphids, including *M. persicae* and *A. craccivora*. In April 2025, a second permit was issued for the anthranilic diamide compound chlorantraniliprole, valid until April 2027. Importantly, the permit for this insecticide covers 'Heliothis and other lepidopteran larvae' so in addition to constituting a complement to the two insecticides registered for use against *Helicoverpa* (also known as Heliothis) (see above) the permit for chlorantraniliprole provides for the first time an option specifically for use against Lepidoptera in other genera including *Ant. catalaunalis*. This systemic insecticide has performed well against *Ant. catalaunalis* in Indian trials [157] so is likely to be useful in Australia.

Future control of a larger range of pests in sesame, and capacity to manage insecticide resistance with a suite of active ingredients, will require approval from the APVMA of additional special use permits (as currently in place for pirimicarb and chlorantraniliprole) and, in the longer term, variation in registrations for products to allow use in sesame (as currently for methomyl and nuclear polyhedrosis virus). The latter process is not straightforward, typically involving submission of an application through the APVMA's online portal, the type of which depends on the complexity of the change, supported by scientific evidence that may include efficacy against the new pest, crop safety, and residue trials for food products. If approved, the product label is updated to reflect the new pest species, along with any changes in use instructions or safety measures. If the new use is already established in other countries with similar regulatory standards, the APVMA may accept international data to support the application. The consequence of this rigorous APVMA regulatory framework is that insecticide use to control sesame pests is currently limited to a small range of active ingredients and limited pest taxa targets so alternative, non-chemical measures are especially important to minimise the risk of pesticide resistance in the emerging industry.

Among non-chemical measures for sesame pest control, the manipulation of sowing date may make a substantial difference to levels of pest damage. With sesame sown in Ethiopia immediately after the beginning of the wet season having less damage from *Ant. catalaunalis* and higher grain yields than sowing dates 10 or 20 days later [158], and in Iraq sowing in May led to less damage than June or July [159]. Notably, however, another Ethiopian study found the opposite effect, with delayed sowing of sesame after the start of the wet season having lower levels of *Ant. catalaunalis* infestation, although yields were still higher with the earlier planting [160]. Cultivar traits may also be important for pest resistance, for example sesame genotypes with more leaf trichomes were found to be more attractive to ovipositing *Ant. catalaunalis* moths [161] and had a higher incidence of the sucking pests *B. tabaci, O. albicinctus and N. tenuis* [162].

Integrated pest management systems for sesame can include economic damage thresholds for insecticide sprays (particularly for Lepidopteran pests such as *Antigastra* and *Spilosoma*), deep ploughing to destroy pest pupae in the soil, rotation with alternative crops such as potato, chickpea, urid bean, and cowpea, and intercropping [147,152,159,163]. A study focused specifically on sesame gall midge found that crop rotation with sorghum reduced flower abortion and number of galled capsules by two thirds compared to continuously grown sesame [148]. There is also evidence from Iran that weed control methods, including wheat straw mulch and ground cover plantings of marigold between sesame rows, can reduce pests in addition to suppressing weeds, and improving seed yields [164].

Intercropping plots of sesame with pearl millet, green gram, black gram, or groundnut in 4:1 or 6:1 ratio reduced *Ant. catalaunalis* incidence to between half and two thirds of that seen in pure sesame [163,165]. But despite both these studies demonstrating lower pest damage, sesame yields per hectare (even after accounting for the reduced area available for sesame in intercropped plots) were usually higher in the pure sesame plots or at best roughly equivalent, suggesting that the benefit of reduced pest damage was offset by competitive or antibiosis effects of the intercrops on sesame plants. Nonetheless, it may still be worth trialling field scale experiments where the intercrop is not grown as closely to the sesame as in the small plots used in these experiments. Even if sesame does not directly benefit from intercropping despite reduced pest levels, there is the possibility mixed cropping may still lead to higher profits for the grower if the intercrop is also of high value, as was the case with sesame/groundnut mixed cropping plots as reported by Manisegaran et al. [163]. Indeed, sesame has been shown as highly effective as a secondary crop at reducing pest damage and allowing higher yields with lower pesticide use in rice [166]. There may therefore be potential for sesame to be integrated as a companion and/or rotated crop into existing cropping systems (e.g., rice, legumes, or sorghum), pending further field trials.

Other possible pest management methods involve the application of oils or plant extracts to the crop, with reports in India and Bangladesh of Indigenous natural products such as neem leaf or seed extract, custard apple or *Polygonum orientale* leaf extract and castor oil as leading to near or similar levels of pest reduction and yield as the pesticide endosulfan, and at much lower economic and environmental cost [167–169]. Most of these alternative methods have only been evaluated in small plots (e.g., 2 m $\times$ 3 m) rather than whole treated fields; however, this is likely to mean that insects simply avoided a small plot treated with an extract or intercropped and moved to a nearby alternative. If oviposition deterrence is the main mechanism for its effect, treating entire fields of sesame with these oils or extracts could result in an initially high threshold of host plant acceptance by the insects to be lowered by repeated contact during searching [170]. Depending on whether the area of the crop exceeds the typical flight range of an ovipositing female and the number of eggs laid on the crop may be like untreated fields.

In relation to the scope for biological control, there are numerous reported natural enemies of sesame pests. While often not identified to species level, the main guilds of natural enemies reported in sesame include lady bird beetles, assassin bugs, syrphus flies, lacewings, tachinid flies, ichneumonid larval parasitoids, and egg parasitoids such as Trichogrammatidae and Platygastridae [146,171], although these studies did not report which pests specifically each of them attacks. On the other hand, Sarazú-Pillado et al. [172] compiled a list of thirty-nine parasitoids that attack *Ant. catalaunalis,* and in a survey found seven species attacking the pest within its invasive range in Mexico. An equivalent study in Columbia found four parasitoids, none of which exerted strong control on populations of *A. catalaualis* [173]. Both studies provided a compiled list of *A. catalaualis* parasitoids including two species found in Australia: *Trathala flavoorbitalis* (Cameron) and *Phanerotoma* *hendecasisella* (Cameron). In a study in Bangladesh, spiders (belonging to four different families) were the most consistent group of natural enemies, being present throughout the crop growth stages, with other natural enemies including praying mantises, predatory bugs, coccinellid beetles, syrphid and tachinid flies, vespid predatory wasps, and black ants [149]. They also reported that braconid parasitoids in the *Apanteles* genus attacked the caterpillars of *A. styx* and *S. obliqua,* while a *Temelucha* parasitoid (Ichneumonidae) attacked *Ant. catalaunalis.* Bioinsecticides such as *Beauveria bassiana* and *Bacillus thuringiensis* have also shown potential for keeping *Ant. catalaunalis* numbers below threshold while minimizing the negative impacts on pollinating bees [174].

4.6. Pest Species Profiles

4.6.1. Sesame Leaf Webber/Capsule Borer *Antigastra catalaunalis* Duponchel (Lepidoptera: Crambidae)

This species was present in large numbers in experimental plantings in Emerald, Queensland (J. Liu and G. Gurr pers. obs.) and Tully, Queensland (L. Jones and G. Gurr pers. obs.) (Figure 9A–C), and destroyed an early-stage experimental planting in Kununurra, Western Australia (R. Flynn, pers. Comm.). It has a very wide geographical distribution, encompassing most of Africa, the Mediterranean, the Middle East, India, China, Japan, Southeast Asia, Australia (all mainland states), and tropical North and South America [106]. The adults fly at night in temperatures at or above 17 °C, and in favourable winds can disperse as far as 1700 km over 10 days [174]. In a study of its life cycle, Ahirwar et al. [167, 175] reported that eggs are laid singly on sesame leaves, capsules, and branches and average 0.36 mm in diameter, and usually hatch after 48 to 74 h. After hatching, first instar larvae initially feed on the leaf epidermis or in mines within the leaf tissue, later starting to bind together leaves on a shoot with silk and feeding within the rolled-up bunch of leaves webbed together (Figure 9C), or boring into pods [175].

Figure 9. (**A**): *Antigastra* adult Tully, QLD. January 2025 (G. Gurr), (**B**): *Antigastra* larva Emerald, QLD. April 2024 (G. Gurr), (**C**): *Antigastra* feeding site. Tully, QLD January 2025 (G. Gurr), (**D**). Green peach aphids (*Myzus persicae*) on a sesame leaf in Orange, NSW in March 2025 (L. Jones). (**E**). Green vegetable bug adult Kununurra, WA January 2025 (L. Jones), (**F**) Green vegetable bug nymphs. Emerald, QLD April 2024 (G. Gurr).

The larvae develop through five instars, with the larval period usually taking between 10 days in ideal summer conditions and 33 days during north India's coldest month [176]. Mature larvae pupate in leaf litter on the ground, with the pupal period ranging from 4 to 12 days, again dependent on temperature [176–178].

Adults live for 4–9 days (males) and 6–12 days (females) under tropical conditions [176,178]. Moths typically feed on nectar early in the evening, especially males, with mating thought to occur later in the night and oviposition in the early morning (04:00 AM–07:00 AM). Female lifespan fecundity averages around sixty eggs, but can vary from 20 to 90, and depends on the time of year, with fecundity peaking during summer [177,179]. Despite warm temperatures accelerating development and increasing fecundity, extremely elevated levels of heat and humidity have a negative impact. The ideal conditions for population growth are at cool (for India) maximum temperatures of around 29 °C and 71% humidity [180]. Eggs are usually laid on the undersides of new leaves, apex of twigs or on flowers and pods [179]. Whilst this species is generally considered a specialist sesame herbivore, the host plant range of *Ant. catalaunalis* includes species in at least seven families, mostly within the order Lamiales, with the largest number of hosts within Pedaliaceae (which includes sesame and its wild congeners) and Plantaginaceae [106,181].

Regarding mating behaviour, Narayanan [182] provided detailed observations in flight cages of courtship and mating behaviour, which initially involved the female approaching the male while rotating her antennae, followed by the male fluttering his wings and approaching the female once she was near. Mating was end-to-end and lasted about 30–40 min [182]. In a study on pheromones, Narayanan and Nadarajan [183] found in olfactometer and field experiments that males were not attracted to live female odours, female headspace volatiles collected during mating periods of the night, or live female-baited field traps, but females were attracted to live males and male volatiles in Y-tubes and live-male baited field traps, suggesting it was the males not females that produce pheromones. Male-produced pheromones are common in moths, although they typically function as close-range rather than distance attractants [184]. While it would be premature to dismiss the possibility that *A. catalaunalis* females produce a long-distance pheromone that was not produced in Narayanan and Nadarajan's [183] olfactometer and field experiments because of their confined condition, the case for a male-produced pheromone that can function as a distance attractant seems reasonably convincing. Given the value of pheromone traps (especially those attracting females) for pest monitoring and control, this avenue could be worth exploring further with the aim of developing *A. catalaunalis* specific pheromone lures.

Determination of damage thresholds is a key aspect of pest management, and Athya and Panday [185] evaluated the impact of one through to six larvae on caged sesame plants (TKG-22 variety) and found a steep decline in yield. Seed yield from plants with just two larvae (2.4 g) was little more than a third that of the control plants with no larvae (7.0 g). Although they only evaluated two plants per treatment, the yield averages for 3, 4, 5, and 6 larvae were all even lower than 2.4 g. Based on these findings, and cost of profenophos insecticide spraying, they derived an economic injury spray threshold of 0.74 larvae per plant. Athya and Panday [185] based thresholds on damage percentage rather than number of insects and estimated that endosulfan spraying should occur at or before 10% damage to sesame plants is reached. The threshold partly depends on the cost of insecticide and market value of sesame yields, with Choudhary and Singh [51] finding the economic injury level was 1.75 larvae per m^2 for spraying carbaryl and 2.75 per m^2 for spraying endosulfan. Whether these thresholds can be generalised to other sesame varieties is not clear. For example, Karuppaiah and Nadarajan [161] found that varieties with more leaf trichomes are more likely to be oviposited on by *Ant. catalaunalis.* High phenol content and lower levels of reducing sugars in leaves was also associated with lower levels of damage [161]. Young sesame plants are more vulnerable, with Menon [177] reporting that one caterpillar can kill 2 or 3 plants in a week if the infestation occurs at an early stage. In addition to the insecticides mentioned above, a recent study comparing mixed insecticide formulations on sesame pests in India found Thiamethoxam + Lambda-cyhalothrin and Profenophos + Cypermethrin to be the most effective at reducing *Ant. catalaunalis* leaf, flower, and capsule damage [186]. Three other studies testing individual chemicals on *Ant. catalaunalis* found Chlorantraniliprole to be the most effective insecticide [187–189].

4.6.2. Green Peach Aphid (*Myzus persicae*) (Hemiptera: Aphididae)

This species was seen in significant numbers on leaves and green pods of sesame plants in Orange, NSW (L. Jones pers. obs Jan 2025), and Jinghi, QLD (L. Jones pers. obs. May 2025) (Figure 9D). *Myzus persicae* (Sulzer) has an almost global distribution [190] and is one the world's most economically significant aphid pests [191]. It feeds on at least four hundred host plant species across forty families, many of which are important crops [192]. Adults measure around 2 mm in length and exhibit colour variations from light green to pink or red, with winged forms displaying dark dorsal markings and wingless adults typically pale green or yellowish. Adults produce clonal nymphs that resemble the wingless adults in coloration and form but are much smaller as neonates. Although *M. persicae,* like most aphids, can produce both males and females for sexual reproduction prior to overwintering in the egg stage, in tropical/subtropical areas they reproduce asexually year-round on sesame, a generation takes about 14 days when reared at 26 °C [193,194]. These aphids can be differentiated from cotton aphid and many other aphid species by the presence of tubercules on the head of *M. persicae* and long pale-coloured siphunculi on the abdomen. In sesame cultivation, *M. persicae* poses a significant threat and it is included in the 'top nine' pests of sesame by Langham [155]. The aphids feed on the phloem sap, leading to reduced plant vigour, stunted growth, and potential yield losses. Additionally, they can vector over a hundred plant pathogens [192], such as Cowpea aphid-borne mosaic virus (CABMV), which causes yellowing, leaf curling, and internode shortening on sesame [23].

Management of *M. persicae* in sesame involves integrated pest control strategies. While chemical insecticides are commonly employed, concerns about resistance development and environmental and health impacts of pesticide residues have led to increased interest in alternative methods [5]. Insecticide resistance is extremely prevalent in this aphid, having evolved at least seven independent resistance mechanisms to organophosphate, carbamate, pyrethroid, cyclodiene, and neonicotinoid classes of insecticides [195]. Indeed, a sesame trial in Nigeria found that spraying lambdacyhalothrin doubled densities of *M. persicae* while all other pests were significantly curtailed [144]. In Australia, insecticide resistance in *M. persicae* led to the use of newly developed insecticides such as sulfoxaflor (registered in 2013); however, low-level sulfoxaflor resistance is now widespread having evolved independently in multiple locations across Australia [196]. Biological control agents, such as predators, fungal pathogens, and parasitoids have shown promise in reducing aphid populations, however [197–199]). Additionally, cultural practices, including the use of resistant sesame cultivars or growing 'living mulches' of calendula between sesame rows, may help mitigate infestation levels [144,164]. Implementing these integrated approaches is crucial for sustainable sesame production and minimizing the economic losses attributed to *M. persicae.*

4.6.3. Green Vegetable Bug *Nezara viridula* Linnaeus (Hemiptera: Pentatomidae)

This species was present in significant numbers in experimental plantings of sesame in Emerald, Queensland (J. Liu and G. Gurr, pers. obs.) and was present in low numbers on trial sesame in Kununurra, Western Australia (L. Jones, pers. obs.) and Tully, Queensland (G. Gurr, pers. obs.) (Figure 9E,F). Commonly known in Australia as the green vegetable bug, this pest is extremely widespread, occurring throughout all regions between 45 degrees north and south of the equator [200]. *Nezara viridula* has been present as a pest in Australia since 1916 and has spread to all mainland states [201]. Initially a significant pest, subsequent introduction of the egg-parasitoid wasp *Trissolcus basalis* was highly effective at reducing pest outbreaks, particularly in Western Australia [201]. The adults are 12–13 mm in body length and are strong fliers [200]. Eggs are laid in masses of about 70–100, with the gregarious nymphs developing through five instars before adulthood [202]. Their host range is broad, encompassing thirty or more plant families [200], although only a small subset of host plants, chiefly soybean, conferred high egg-to-adult survival in a study in Southeast Queensland [203]. Sesame appears to be a very high-quality host plant for *N. viridula,* with a study in Brazil finding that survival, adult longevity and fecundity were all roughly twice as high when reared on sesame compared to soybean [204].The high protein content of sesame also allowed adult bugs that had been reared on sesame to survive 30 days without food compared to around 10 days without food if reared on soybean [204]. Nymphal development on sesame took 34–40 days at 25 °C depending on cultivar [204,205].

It appears that in many cropping systems, controlling weeds can reduce the prevalence of *N. viridula,* as it frequently uses these as host plants to persist when the crop is harvested [203,206]. Indeed, improved control of weeds in crops such as soybean is considered a primary reason for the declines of *N. viridula* in the USA and Brazil since the 1990s, especially in comparison to other stink bug pests that can remain dormant or survive in crop stubble after harvesting rather than relying on alternative hosts in the cropping area to survive [206]. Another reason for the decline was an increase in parasitoid abundance during that time, partly because of more selective insecticide use [206]. This makes sense given the successes in Australia with *T. basalis* [201], but unfortunately this wasp is repelled by sesame—never ovipositing into egg masses and instead immediately flying away and cleaning themselves after any contact with sesame plants [207]. This may be why trial plantings of sesame in Gatton, QLD, in the 1980s were so heavily attacked by *N. viridula* [207]. For this reason, weed control methods may be even more important—although given the enhanced starvation resistance of sesame reared *N. viridula* [204], it is also possible they would be less reliant on weed hosts in sesame compared to bean crops. Another avenue for control is using an area of earlier maturing crop as a trap crop, as later stage crops tend to be more attractive to *N. viridula* [208].

Australian *N. viridula* falls into two geographically and genetically distinct populations, with a European population predominating in the southeast, and an Asian population in the northwest [209]. They found introgression had occurred in a limited area of overlap, and the distributions of the two populations (or subspecies) correlated with average summer temperature. No host associated genetic differentiation was seen, and there is no evidence for differences in host use across the two subspecies present in Australia [209].

Nezara viridula can potentially be controlled using insecticides (subject to APVMA permit), such as cyfluthrin, dicrotophos, oxamyl, and thiamethoxam; however, these are also toxic to their natural enemies [210] which can make their application problematic. Possible emerging methods of control include RNA interference targeting the *Chitin synthase* and *Acetyl-CoA carboxylase* genes and resulting in 75% mortality of *N. viridula* when evaluated by Riga et al. [211].

4.6.4. Tomato Bug, *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae)

This species was present in significant numbers in experimental plantings of sesame in Katherine, Northern Territory (G. Gurr, pers obs September 2024) and Gurgeena and Jinghi in southern Queensland (L. Jones pers. obs. May 2025) While official location records in Australia are patchy, it seems to have a wide distribution across the mainland [190], and globally is widespread in tropical and subtropical areas including Africa, India, east Asia, Indonesia, the Middle East, the USA, and Mexico [212]. *Nesidiocoris tenuis* is an omnivorous mirid bug that feeds on both plant tissues and other pest herbivores such as whiteflies, and therefore its status as a pest or beneficial is contentious [213–215]. Although Dilipsundar et al. [140] reported *N. tenuis* as one of the major pests of sesame, it is a known predator of whitefly (*Bemisia* tabaci) [216], another significant sesame pest [140]. On tomato, it can cause necrotic rings on the plant when prey is scarce, but otherwise it feeds mostly on insect prey [213,217], suggesting the ratio of *N. tenuis* relative to other pest herbivores will determine whether it acts as a pest or beneficial.

On sesame, in contrast to several other crops such as tomato, eggplant, and capsicum, *N. tenuis* showed a high survival rates (59%) from egg to adult when feeding on the plant alone with a generation time of just over 3 weeks. Thus, suggesting a greater tendency for pestilence on sesame compared to other crops [218], but even so reproductive output was higher for bugs reared on sesame with Mediterranean flour moth eggs as an additional food source [209]. A recent study found that control of the pest moth *Tuta absoluta* on tomato through *N. tenuis* predation was improved by the presence of sesame as a companion plant [217]. They also found levels of *N. tenuis* herbivory on tomato was three times lower when sesame was present. Indeed, sesame has been recommended as an intercrop with tomato in Senegal and Florida to promote the biocontrol services of *N. tenuis* as a predator of *B. tabaci* and *T. absoluta* [216,219].

Nesidiocoris tenuis is attracted to herbivore induced plant volatiles of sesame, making it more likely to colonise sesame if it is already infested with a Lepidoptera pest [220]. Because the mirids feed on the sesame plant directly as well as preying on the pest caterpillars, their presence led the sesame plant to produce a different blend of *N. tenuis* induced volatiles. After four days' exposure to sesame, *N. tenuis* was more attracted to induced volatiles of a different plant, eggplant, which it had previously found less attractive, although it was still more attracted to induced than undamaged sesame [220]. If olfactometer tests are a reliable indicator of behaviour in the field, it suggests the mirids may be likely to target individual sesame plants under attack from herbivores over intact ones and possibly curtail their spread; however, in conditions where other herbivores are scarce, they may become significant pests and need to be controlled.

As a pest on sesame, a recent study in India found that incidence and damage was positively correlated with morning relative humidity and negatively correlated with maximum temperature [221]. However, it is possible some of the significant meteorological correlations in this study are spurious type 1 statistical errors due to the considerable number of comparisons. Another study rearing *N. tenuis* at various temperatures found they were capable of development and reproduction at temperatures from 20 °C to 35 °C, however at 40 °C and 15 °C there was almost no reproduction, with 40 °C also causing remarkably high mortality. Egg development took 149 degree-days while nymphal development 182 degree-days [214]. Optimal temperatures for reproductive output within the 20–35 °C range can vary depending on strain, however [222]. *Nesidiocoris tenuis* is susceptible to applications of essential oils as pest control, in particular neem seed kernel and garlic oils [168,223] with sublethal concentrations of garlic, fennel, lavender, and anise oils also leading to impaired orientation and fertility [223]. It can also be controlled with endosulfan sprays [168].

4.6.5. Silverleaf Whitefly *Bemisia tabaci*/*B. argentifolii* (Hemiptera: Aleyrodidae)

These insects were present in significant numbers in experimental plantings of sesame in Emerald, Queensland (G. Gurr, pers obs 2024). The silverleaf whitefly is not one species, but rather a complex of at least twenty-four morphologically identical cryptic species. These insects vary in both the range of plants attacked and in which plant diseases they vector [224], and their nomenclature remains unclear and contested. The most invasive and damaging of these cryptic species are the B (also called MEAM1 and *Bemisia argentifolii*) and Q (MED) biotypes, which both have very extensive host ranges [224]. Biotype Q has not been recorded in Australia; however, biotype B (*Bemisia argentifolii*) was first detected in Australia, and in 1994 Gunning et al. [27] established it as the most common *Bemisia* pest in Australia [225]. Three other biotypes or species within the *B. tabaci* complex occur in Australia, including two native Australian biotypes (AUSI and AUSII) and the exotic Asia II biotype [226]. AUSI AUSII have been confirmed to be distinct species with genetic differentiation, host plant associated differences and unique mating signals. *Bemisia argentifolii* is widespread across eastern, northern, and southwestern Australia, though uncertainties remain about distributions of the other cryptic species [217,227,228].

While *B. tabaci* is commonly reported as a major pest of sesame [141], given that only morphological identification of *B. tabaci* was performed, it is not clear which biotypes within the cryptic species complex were attacking sesame in each case. Ahirwar et al. [168] reported *B. tabaci* whitefly nymphs and adults were significant pests, feeding from leaves, flowers, and pods and causing curling leaves, stunted growth, and yellow spots on leaves. Unlike some of the other significant pests, *Bemisia tabaci* infestation of sesame in India did not show a correlation with any meteorological parameters such as temperature, humidity, or rainfall. While development time on sesame does not appear to have been evaluated, on bean crops egg–adult development took 18–27 days at 27 °C [221].

Resistance to organophosphate and (to a lesser extent) pyrethroid insecticides is widespread in *B. argentifolii* populations across Australia but absent in AUSI whiteflies [225]. *Bemisia argentifolii* in Australia has also been evolving resistance to the juvenile hormone analogue pyriproxyfen, with resistance alleles widespread in cotton growing localities; however, bifenthrin and diafenthiuron are (as of 2017) still effective [229]. In India, a recent study testing mixed formulations of insecticides against *B. tabaci* on sesame found Acephate/Imidacloprid and Pyriproxyfen/Fenpropathrin mixes to be the most effective, although neither reduced pest levels to below 50% of that seen on untreated controls [186]. Plant oils such as neem, soybean, mint, or geranium applied as a spray to sesame plants seem to have potential for reducing whitefly numbers, along with other kinds of sucking pests [168,230]. There is also some evidence that sesame genotypes with high foliar acidity are attacked less by whiteflies [231], and indeed sesame oil may be effective as a means of controlling whiteflies on other crops [232].

4.6.6. Green Mirid *Creontiades dilutus* Stål (Hemiptera: Miridae)

This species appeared on trial sesame plantings in Katherine, Northern Territory (G. Gurr, pers. obs. September 2024). The green mirid, *Creontiades dilutus* Stål (Hemiptera: Mmiridae), is a widespread native Australian insect that has been established as a crop pest, particularly on cotton. It feeds by injecting enzymes into plant tissue before sucking up the liquid digested mixture [233]. *Creontiades dilutus* is usually controlled by insecticide sprays, particularly fipronil [234,235]. They tend to be attracted to legumes, which can be used as trap crops, as shown by Hori and Miles [236] who found that lucerne inter-plantings on cotton fields was effective at luring mirids away from the cotton crops. When reared on green beans, egg and nymphal development took 69- and 157-degree days above the thresholds of 15 and 16 °C, respectively [237]. Hereward [238] identified a list of over

70 host plants green mirids have been found feeding on, but despite this apparently high level of polyphagy, green mirids in the wild are consistently abundant on just two plant species, *Cullen cinereum* and *Cullen australasicum*, both native legumes found in central Australia [239].

As *C. dilutus* is not found outside of Australia, and sesame has not been grown as a crop to any significant extent in Australia, little information is available about its potential impact on sesame. Given that green mirids have a distribution covering most of the Australian continent [240] and frequently disperse long distances [239], there is certainly potential for them to arrive at sesame crops, but whether they are likely to become a major pest remains to be seen.

4.6.7. Rutherglen Bug *Nysius vinitor* Bergroth (Hemiptera: Lygaeidae)

This species was found in significant numbers on experimental sesame plantings in Katherine, Northern Territory (G. Gurr, pers. obs. September 2024) and Kununurra, Western Australia (L. Jones, pers. obs. January 2025). The Rutherglen bug is a generalist herbivore native to Australia with a host range encompassing at least twenty-six plant families [241]. It is particularly prevalent as a pest on grains (particularly sorghum) and oilseed crops such as canola and sunflower, on which both nymphs and adults develop and feed. There is no published literature on this species as a sesame pest, as it is not found outside Australia; however, several other *Nysius* species are sesame pests [140].

Rutherglen bugs readily migrate, and fly both during the day and night, with warmer temperatures both during the day (above 27.7 °C) and in late evening (above 19 °C) more likely to lead to mass flights—detectable using light traps (night) or suction traps (day) [242]. Nymphal development was best at temperatures from 20 to 35 °C, with egg and nymphal development taking 70 and 225 degree-days above 14.5- and 15-degree thresholds, respectively [243]. Smith [243] reported *N. vinitor* oviposited on several weeds including sow thistle and cudweed, which both allowed it to complete development. He also reported that females have an oviposition period of 13 to 25 days and fecundity of 134 to 435 eggs, and that first and second instar nymphs were sedentary whereas later instars frequently wander across the soil between plants. This means nymphs will be able to infest plants in neighbouring rows or beds even if they were missed by adult females depositing eggs. The insect has been described as a transient or sporadic pest, though when it does occur, large outbreaks are common [244,245].

For controlling Rutherglen bug outbreaks, pyrethroids have been reported as being the most effective class of insecticides [246]. McDonald et al. [247] found a range of insecticides could effectively reduce *N. vinitor* populations but reported the longest lasting protection against reinvading Rutherglen bug was with acephate (an organophosphate), cypermethrin and deltamethrin (both pyrethroids).

5. Discussion

The present review highlights the diversity and potentially damaging impact of diseases and insect pests on the emerging sesame industry in Australia. Disease threats to Australian crops include fungal, oomycete, bacterial, and viral pathogens. Multiple international reports have indicated the effectiveness of various disease management tools used alone or in combination for managing these sesame diseases. It is essential to evaluate these disease management tools under Australian conditions to determine their practicality. A key constraint is the fact that there are no currently registered pesticides for disease management in Australia. Compounding this, to date, the only documented research on sesame disease in Australia was conducted by Matchett in 1995 [30]. Subsequent reports have merely noted the detection of diseases in sesame trials and commercial plots in Northern Australia. Hence there is a substantial knowledge gap about the potential efficacy of chemical and non-chemical methods for protecting a developing sesame industry from diseases.

Among pests, a total of fifty-six taxa is identified as potential pests but even with the limited evidence base currently available from field surveys and a small published Australian literature, it is possible to comment on the relative importance of pest species. Notably, *Antigastra catalaunalis*, *Aphis gossypii*, *Myzus persicae*, *Nysius vinitor*, Nesidiocoris *tenuis*, *Nezara viridula*, Bemisia *tabaci*, and *Creontiades dilutus*, emerged as key pests of concern, given (i) their presence in experimental plantings in northern Australia in 2024 and 2025 (ii) their status as significant sesame pests globally, and (iii) the impacts of these pests on other important Australian crop species. Most of the foregoing species are known to cause significant economic damage globally, though *N. vinitor* and *C. dilutus*, are native Australian hemipterans. These are significant pests of other crops including oilseed canola. The fact that sesame is attacked by native Australian pests for which overseas experience can offer no leads for effective management, coupled with the many abiotic, biotic, agronomic, economic, and seasonal differences between Australian and overseas production conditions, underscore the need for the development and testing of tailored pest management strategies to ensure high-yielding and sustainable sesame production in Australia. The aphid, *A. gossypii*, a widespread pest in Australian cotton and cucurbits, may cause both direct feeding damage to sesame but also poses an indirect threat as a vector of mosaic virus [149]. This mirrors findings from sesame-producing regions worldwide, where aphids serve as primary virus vectors. Another sucking pest, *N. viridula*, a widely established pest in Australia and considered a major threat to soybean and pulses, has been observed in experimental sesame plantings. Given its high reproductive potential on sesame [203], this species may require initiative-taking management before it becomes a major constraint on commercial sesame production. *Nesidiocoris tenuis* has been recorded in considerable number in some sesame plantings in northern Australia. However, it is omnivore in nature, feeding on insect pests whitefly, as well as on plant tissues, meaning that work is required to establish its net effect on sesame under Australian conditions. Of all pests. *Ant. catalaunalis* is that most likely to be a major biotic constraint on sesame yields in Australia.

Antigastra catalaunalis is one of the most damaging sesame pests worldwide, particularly in India, Nigeria, Ethiopia, and Uganda. Reports from Greece suggest that this pest is expanding its geographic range. In Australia, it has been observed on sesame in Queensland, the Northern Territory, New South Wales, and Western Australia, causing severe damage in some cases so poses a major risk to the establishment of a profitable sesame industry. In contrast to polyphagous pests such as *Helicoverpa armigera* and *N. viridula* which are well-known pests of summer crops including cotton in Australian agriculture, the *Ant. catalaunalis* is a specialist sesame feeder so Australian growers have little to no experience of managing this pest. The present review suggests that some overseas strategies could be implemented to beneficial effect in Australia.

Pest management strategies evaluated overseas against sesame pests offer potentially valuable insights for Australian sesame production. Additionally, most of the foregoing pests are also significant in Australian crops other than sesame. Accordingly, there is a significant body of information on which to base pest management strategies for an emerging sesame industry. For example, a foundation of IPM is monitoring of pest densities. According to current (2024–2025) cotton pest management guidelines, *M. persicae* and *B. tabaci* pest monitoring is through visual leaf sampling to count individuals [248]. These guidelines also recommend visual sampling for *C. dilutus* and *N. viridua* monitoring, along with netting and beat sheets—with the latter recommended particularly for larger plants. Internationally, aphid monitoring has used suction traps and yellow sticky traps as alternatives to visual sampling, sometimes with attempts to statistically forecast pest numbers, with varying degrees of success [191]. In his sesame pests guide, Langham [155] also suggested yellow sticky traps in addition to visual surveys for monitoring whiteflies. For *Ant. catalaunalis*, some overseas sources have reported pheromones, but these do not appear to be widely used in monitoring traps [174,249]. This approach is one that merits research attention since this pest can cause important level of damage at low densities so early detection (before presence of foliar damage is evident) would be valuable.

Insecticide-based approaches against sesame pests, particularly imidacloprid, acetamiprid, thiamethoxam, and lambda-cyhalothrin, have shown efficacy in reducing pest populations by 75–100% [144,250]. However, resistance development *in M. persicae* and the environmental concerns associated with chemical control necessitate an integrated pest management (IPM) approach. Non-chemical strategies, including adjusted sowing dates [158,159], crop rotation [148], and intercropping [163,165], have demonstrated potential for reducing pest incidence. However, inconsistent results in different environments [160] highlight the need for region-specific validation in Australia. Similarly, neem-based biopesticides and other plant-derived extracts have shown promise [154,168], but most trials were conducted in small plots, necessitating large-scale field studies to determine their feasibility under commercial conditions. Such natural product-based plant protection compounds do usually offer the advantage of low toxicity to beneficial arthropods including pollinators and natural enemies so are more compatible with an IPM approach that also includes biological control and focuses on the entire pest complex rather than a pest species by pest species granular approach.

Biological control presents a promising avenue. The presence of *Trathala flavoorbitalis* and *Phanerotoma hendecasisella* in Australia [172,173] suggests that these parasitoids could contribute to *Ant. catalaunalis* suppression. Earlier efforts in Australia to introduce *Trissolcus basalis* for controlling *N. viridula* [201] demonstrated the effectiveness of classic biocontrol, suggesting that targeted introductions of natural enemies could enhance pest suppression in sesame.

Disease management and pest management are linked. Effective control of sucking pests is important for preventing disease being introduced into the plants, and the inverse may also be true given plants infected by disease can become more susceptible to insect attack [251]. Some of the foregoing cultural approaches for disease management including crop rotation, intercropping, trap crops, and optimizing sowing time can contribute to the effective IPM of pests. Nonetheless, additional measures will also be required for pest management, such as economic injury thresholds and biocontrol agents.

6. Limitations and Future Research Directions

This review provides the first assessment of potential diseases and pests affecting sesame cultivation in Australia. However, several limitations need to be considered. First, the lists of diseases and pests were compiled based on global records and preliminary field observations. It is important to note that not all these species will become significant pests under Australian conditions. Future multi-season field trials will be essential in identifying which species cause consistent economic damage. From this information, Integrated Disease Management (IDM) and Integrated Pest Management (IPM) strategies can be developed and evaluated to address multiple diseases and pests, as well as various control methods.

There is a specific need to determine the damage thresholds of the major diseases and pests in Australian production settings. Unlike many overseas production environments, sesame farming in Australia will only be viable if grown extensively, with crops typically covering tens of hectares and utilizing important levels of mechanization due to the excessive cost of labour.

Additionally, while our study reviews existing disease and pest management strategies, their effectiveness in Australian climatic conditions and cropping systems remains uncertain. Field trials should investigate the roles of crop phenology, natural enemy populations, and disease and pest thresholds in guiding site-specific integrated management programs. Given the importance of sesame as an oilseed crop and its potential integration into Australian cropping systems, further research should explore its role as a trap crop or in crop rotation for disease and pest suppression in legume, rice, or sorghum production.

There are several important components of an Integrated Disease Management (IDM) strategy for sesame that require research attention:

1. Rapid Disease Diagnostics and Assessment Tools: Develop tools that provide immediate results by leveraging modern molecular biology approaches, satellite imagery, and remote sensing technologies.
2. Disease Incidence and Distribution: Identify the incidence and distribution of each sesame disease and assess their impact on production to ensure effective management in the field.
3. Understanding Pathosystems: Gain insights into the interactions between host, pathogen, and environment to make informed decisions in disease management, without compromising agronomic or economic goals.
4. Diversity of Plant Pathogens: Research the diversity of different plant pathogens to aid breeding programmes aimed at enhancing resistance and tolerance.
5. Site-Specific Screening Tests: Conduct screening tests on local and introduced varieties and strains to select for resistance to local diseases.
6. Genetic and Breeding Approaches: Develop varieties with resistance or tolerance to priority diseases through genetic and breeding methods, including generating genetic variability by transferring alien genes from closely related or unrelated sources using wide hybridization and biotechnological tools. Genetic resistance or tolerance is the most effective solution from both economic and environmental perspectives.
7. Reliable Disease Screening Protocols: Establish well-planned and executed protocols for reliable disease screening focused on priority diseases.
8. Utilizing Online Databases: Exploit available online sesame databases that provide valuable information on molecular functions, genome components, gene expression, SSR, SNP, QTL (quantitative trait locus), functional genes, transposons, and genetic maps to support the sesame improvement breeding program.
9. Biochemical and Physiological Studies: Investigate the biochemical and physiological basis of resistance against major sesame diseases.
10. Epidemiological Studies: Conduct epidemiological studies on various priority diseases to inform disease management strategies.
11. Chemical Registration: Screen available chemicals for registration by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for use on priority diseases in Queensland.
12. Biological Agents Evaluation: Survey, identify, and evaluate various biological agents for their efficacy against priority sesame diseases to minimize chemical use in IDM.
13. Development of IDM Modules: Create IDM modules for priority sesame diseases based on current and new knowledge of best management practices.
14. Integration of Resources: Integrate genomic resources, crop production and protection techniques, postharvest practices, crop improvement programs, and capacity building to ensure the successful production of sesame in Queensland.

7. Conclusions

Our research provides a fundamental understanding of the potential diseases and pest challenges affecting sesame cultivation in Australia. By identifying key pathogens and pests, we emphasize the need for initiative-taking monitoring and management strategies. While chemical control may seem appealing for Australian broadacre production systems, experiences with other crops, such as cotton, indicate that Integrated Disease Management (IDM) and Integrated Pest Management (IPM) approaches are essential. These methods not only help prevent resistance but also address environmental challenges that can arise from over-reliance on insecticides. By integrating biological control methods, adjusting planting times, and exploring alternative pest management strategies, we can promote sustainable sesame production. Future research should focus on long-term field evaluations to refine disease and pest management recommendations and optimise yields under Australian conditions.

Author Contributions: Conceptualisation, D.L.A. and G.M.G.; methodology, D.L.A., G.M.G., L.C.J. and J.L.; investigation, D.L.A., L.C.J. and G.M.G.; resources, D.L.A. and G.M.G.; data curation, D.L.A., L.C.J. and J.L. writing—D.L.A., L.C.J., J.L. and G.M.G.; writing—review and editing, D.L.A., L.C.J., J.L. and G.M.G.; visualisation, D.L.A. and G.M.G.; supervision, D.L.A. and G.M.G.; project administration, G.M.G.; funding acquisition, D.L.A. and G.M.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by CRCNA, AgriFutures, and the Broadacre Cropping Initiative BACI (a partnership between the Queensland-Department of Primary Industries and the University of Southern Queensland).

Data Availability Statement: Data supporting reported results are archived in the author's respective institution. Access to information is subject to approval by the data owner.

Acknowledgments: The authors thank Prabuddha Dehigaspitiya for assisting with disease surveillance and sample collection, and Encarnacion Adorada for isolating and identifying the disease-causing pathogen during the initial stages of sesame research at the University of Southern Queensland. The authors have reviewed and edited the output and take full responsibility for the content of this publication.

Conflicts of Interest: The authors have no conflicts of interest to disclose. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

SNMV	Sesame Necrotic Mosaic Virus
CABMV	Cowpea Aphid-Borne Mosaic Virus
TAV	Tomato Aspermy Virus
SeCTV	Sesame Curly Top Virus
CSIRO	Commonwealth Scientific and Industrial Research Organisation
NTDPIF	Northern Territory Department of Primary Industry and Fisheries
EC	Emulsifiable Concentrate
ITS	Internal Transcribed Spacer
APVMA	Australian Pesticides and Veterinary Medicines Authority
SSR	Simple Sequence Repeat
SNP	Single Nucleotide Polymorphisms
QTL	Quantitative Trait Locus
IDM	Integrated Disease Management
IPM	Integrated Pest Management

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