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Diseases of *Cassia* species — a review

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Abstract

A wide range of fungi, two bacteria and several viruses and nematodes have been recorded throughout the tropics on a group of *Cassia* species defined as taxonomically and geographically related to *Cassia rotundifolia*. Although limited information was found on the relative importance of these pathogens, the fungi *Alternaria cassiae, Corynespora cassiicola, Phomopsis cassiae, Pseudocercospora nigricans, Pseudoperonospora cassiae* and *Ravenelia berkeleyii* and the viruses Cassia Mild Mosaic, Cassia Yellow Blotches and Cassia Yellow Blotch are considered the most serious. Specific recommendations are made to evaluate the reaction of *C. rotundifolia* cv. Wynn to these pathogens. The attention of Australian pasture scientists is drawn to recent plans to develop mycoherbicides for controlling pantropical *Cassia* weeds and the implications of their use in South-east Asia and the south-west Pacific.

Resumen

Un amplio rango de hongos, dos bacterias y varios virus y nemátodos se han registrados a través de los trópicos en un grupo de epecies de Cassia *definidas taxonómicamente y geográficamente como afines a* Cassia rotundifolia. *Aunque se encontró información limitada sobre la relativa importancia de estos patógenos, se consideran los más serios los hongos* Alternaria cassiae, Corynespora cassiicola, Phomopsis cassiae, Pseudocercospora nigricans, Pseudoperonospora cassiae *y* Ravenelia berkeleyii *y los virus Mosaico suave y manchados amarillos de* Cassia. *Se hacen recomendaciones especificas para evaluar la reacción de* C. rotundifolia *cv. Wynn a estos patógenos. La atención de cientificos Australianos en pasturas está dirigida a los planes recientes a desarrollar microherbicidas para el control de malezas de* Cassia *pantropicales y las implicaciones de su uso en el Sureste de Asia y el Suroeste Pacifico.*

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Introduction

Cassia, the fourth largest legume genus, comprises approximately 600 species (Duke 1981). Most species are native to tropical and subtropical regions. The genus shows great morphological diversity with tree, shrub and herbaceous species and forms. Various tree species, such as *Cassia fistula* L. — golden shower and *C. grandis* L. f. — pink shower, are popular ornamentals while several herbaceous species, such as *C. obtusifolia* L., *C. occidentalis* (L.) Link and *C. tora* (L.) Roxb., are serious pantropical weeds. Although several species have been evaluated for their potential as tropical pasture legumes, to date one accession of only one species, *C. rotundifolia* Pers., has been released for sown pastures.

Cultivar Wynn (*C. rotundifolia* CPI 34721, round-leafed cassia), originating from the Brazilian cerrados, was registered in 1984 as a productive, high quality, summer growing, herbaceous pasture legume (Oram 1984, Strickland *et al.* 1985). Comparative trials with accessions of several *Cassia* species throughout Queensland and New South Wales during 1981 to 1986 clearly showed that cv. Wynn was superior to other accessions and species tested (Strickland *et al.* 1985, Strickland and Greenfield 1988). Being productive and persistent over a wide range of environments in northern Australia, it offers considerable potential for improved cattle production in this region.

At the time of its release, the only diseases recorded on cv. Wynn was mild leaf spotting caused by *Pleospora* sp. (Oram 1984). Since then, only two other minor diseases have been recorded on the cultivar in northern Australia, slight leaf, stem and pod spotting caused by *Phomopsis* sp. and *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. (Davis, personal communication).

Past experience in Australia with tropical pasture legumes introduced from South America has been frustrating. Highly productive *Stylosanthes* cultivars Cook, Endeavour, Schofield and Fitzroy have been devastated by anthracnose (*C. gloeosporioides*), most probably introduced from South America (Lenné and Calderon 1984). *Macroptilium atropurpureum* (DC.) Urb. cv. Siratro, initially disease-free, is now affected by several serious diseases including rust (*Uromyces appendiculatus* (Pers.) Unger) (Lenné and Sonoda 1985). Lack of exposure of accessions to these diseases during evaluation in Australia, resulted in selection of susceptible cultivars.

Loss of tropical pasture cultivars to serious diseases within a few years of release represents a considerable waste of investment of resources and time. A knowledge of the range of pathogens recorded on *Cassia* species and hence potentially capable of attacking *C. rotundifolia* cv. Wynn is a first step towards avoiding problems now being faced with *Stylosanthes* species and Siratro.

A wide range of fungi, bacteria, viruses and nematodes have been recorded on over fifty *Cassia* species, many of which will never affect *C. rotundifolia* due to taxonomic and geographical barriers. To review only those diseases recorded on *C. rotundifolia*, however, would be short-sighted and not very informative. A compromise was therefore reached to summarize published and unpublished records of diseases of a selected group of *Cassia* species. The objective of this paper is to provide a basic reference for pasture scientists to facilitate identification of diseases detected on *C. rotundifolia* in the future and for quarantine officers to avoid introduction of pathogens. Where information was available, the relative importance of diseases is discussed. Recommendations are made for research on specific diseases.

Taxonomy of *Cassia*

Although all hosts in this paper will be referred to as *Cassia* species to avoid confusion, in a synoptical review of American *Cassia* species, Irwin & Barneby (1982) recognized three genera: *Cassia* — obligately tropical and including trees and shrubs distributed throughout all continents; *Senna* — including trees, woody vines, shrubs and herbs, distributed throughout all continents and Oceania, a few extratropical; and *Chamaecrista* — including shrubs and herbs, widely distributed but primarily American, a few extratropical. *Cassia rotundifolia* was reclassified as *Chamaecrista rotundifolia* (Pers.) Greene.

The most recent treatment of the Australian *Cassia* species, by Symon (1966), recognizes 5 main groups among the endemic species which include representatives of the three genera put forward by Irwin & Barneby (1982).

Cassia species included in this review

Four groups of *Cassia* species are considered sufficiently taxonomically and geographically related to *C. rotundifolia* to be of interest from the point of view of diseases. These are *Chamaecrista* species, the most taxonomically related group; other Brazilian *Cassia* species, included because of their geographical association with and the possibility of co-hosting indigenous diseases of *C. rotundifolia*; Australian endemic *Cassia* species; and widely-distributed *Cassia* species such as ornamentals and weeds (Irwin and Barneby 1982; Symon 1966). The latter two groups are included because of the possibility of diseases spreading from them to introduced *C. rotundifolia* in Australia.

Group 1: Chamaecrista *species*

Diseases have been recorded on 5 species of *Chamaecrista*:

1. *C. absus* (L.) Irwin & Barneby (syn. *Cassia absus* L.) — herbaceous to shrubby; widespread throughout tropical regions; recorded in Australia.
2. *C. diphylla* (L.) Irwin & Barneby (syn. *C. diphylla* L.) — herbaceous; native to Central and South America and the Caribbean.
3. *C. glandulosa* (DC.) Irwin & Barneby (syn. *C. glandulosa* DC.) — herbaceous to arborescent; native to Central and South America and the Caribbean.
4. *C. nictitans* (L.) Moench. (syn. *C. nictitans* L.) — herbaceous to arborescent; native to Central and South America and the Caribbean.
5. *C. rotundifolia* (Pers.) Greene — herbaceous; native to Central and South America.

Group 2: Other Brazilian Cassia *species*

Diseases have been recorded on 9 additional *Cassia* species native to Brazil.

1. *Senna alata* (L.) Roxb. (syn. *Cassia alata* L.) — shrubby to arborescent, also weedy; widely distributed throughout the tropics including the Brazilian plateau; naturalized in North Queensland.
2. *S. pallida* (Vahl) Irwin & Barneby (syn. *C. biflora* Vahl) — shrubby to arborescent; native to South America.
3. *S. latifolia* (G.F.W. Meyer) Irwin & Barneby (syn. *C. hoffmannseggii* G.F.W. Meyer) — shrubby to arborescent; native to tropical South America.
4. *S. macranthera* (Colladon) Irwin & Barneby (syn. *C. macranthera* Colladon) — shrubby to arborescent; native to South America including North-east Brazil; popular ornamental shade tree in the Brazilian cerrados.
5. *S. rugosa* (G. Don.) Irwin & Barneby (syn. *C. rugosa* G. Don.) — shrub; native to Brazilian cerrados.
6. *Cassia sericea* Sw. — native to Brazil.
7. *S. spectabilis* (DC.) Irwin & Barneby (syn. *C. spectabilis* DC.) — shrubby to arborescent; native to the Brazilian cerrados.
8. *S. splendida* (Vogel) Irwin & Barneby (syn. *C. splendida* Vogel) — shrubby to arborescent; native to Brazilian cerrados and coast; common ornamental in Brazil.
9. *S. sylvestris* (L.) Irwin & Barneby (syn. *C. sylvestris* L.) — shrubby to arborescent; native to Brazil.

Group 3: Australian Cassia *species*

Diseases have been recorded on 4 Australian species.
1. *Senna artemesoides* (DC.) Irwin & Barneby (syn. *Cassia artemesoides* DC.) — shrub; common on sandy soils in the Northern Territory, Queensland and Western Australia.
2. *Chamaecrista mimosoides* (L.) Greene (syn. *C. mimosoides* L.) — herbaceous; widespread throughout New South Wales, the Northern Territory, Queensland and Western Australia; also widespread throughout tropical regions of the world.
3. *S. pleurocarpa* (F. Muell.) Irwin & Barneby (syn. *C. pleurocarpa* F. Muell.) — shrub; widespread in drier areas of Queensland and Western Australia.
4. *S. surattensis* (Burm. f.) Irwin & Barneby (syn. *C. surattensis* Burm. f.) — shrub; widespread in northern Australia; also present in Asia, Hawaii and the West Indies.

Group 4 — Widespread Cassia *species — ornamentals and weeds*

i) Ornamentals. 1. *Cassia fistula* L. (golden shower, Indian laburnum) — widespread ornamental tree throughout the tropics; native to South-east Asia; naturalized in North Queensland.
2. *C. floribunda* Cav. (arsenic bush) — ornamental shrubby tree; native to Central and South America; naturalized in northern Australia.
3. *C. grandis* L. f. (pink shower, horse cassia) — ornamental tree in Brazil; native to Central and South America.
4. *C. javanica* L. (pink shower) — ornamental garden and street tree in Central and South America; native to Asia.

ii) Weeds. 1. *Senna hirsuta* (L.) Irwin & Barneby (syn. *C. hirsuta* L.) — widespread, leafy, malodorous herbaceous weed; probably native to Brazil; common in the Northern Territory and Queensland.
2. *S. obtusifolia* (L.) Irwin & Barneby (syn. *C. obtusifolia* L.) (sicklepod) — rank colonial herbaceous weed of crop and wasteland; probably native to the Americas; present in northern Australia.
3. *S. occidentalis* (L.) Link (syn. *C. occidentalis* L.) (coffee senna) — widespread, leafy, malodorous herbaceous weed; probably native to the Americas; common in the Northern Territory and Queensland.
4. *S. sophera* (L.) Roxb. (syn. *C. sophera* L.) — widespread, erect, bushy, herbaceous weed especially of roadsides and wasteland; native to the Americas; present in northern Australia.
5. *S. tora* (L.) Roxb. (syn. *C. tora* L.) (foetid cassia) — widespread, leafy, herbaceous weed; serious weed of pastures and rank colonizer of wasteland; probably native to the Americas; present in northern Australia.

Fungal diseases

Three groups of fungal pathogens recorded on *Cassia* species can be distinguished. Four complexes of fungal species and three individual species are regarded as damaging and/or potentially damaging pathogens to *Cassia* species included in this review (Table 1). A second group including the causal agents of anthracnose, tar spot, powdery mildew, scab, false rust, root, stem and foliage rots are presently regarded as less

damaging while a third group for which only host and distribution information are available is included for completeness. All records cited IMI refer to unpublished records of the International Mycological Institute, Kew, Surrey, England.

Damaging and potentially damaging fungal diseases

i) Diseases caused by Alternaria *species (foliar and seedling blights). Alternaria cassiae* causes foliar blight of several *Cassia* species in India and USA (Table 1) and serious seedling blight of *C. obtusifolia* (sicklepod) and *C. occidentalis* (coffee senna) in the USA (Boyette 1988). Seedling blight is described as severe leaf lesions resulting in defoliation, severe stem lesions developing into cankers, stunting and plant death (Walker 1982). A mycoherbicide CASST™ is being developed from this pathogen to control both sicklepod and coffee senna in cotton, peanut and soyabean plantings in the USA (Bannon 1988).

Alternaria alternata and *A. tenuissima* cause foliar blight of *C. fistula* and *C. tora* in India and Pakistan (Table 1). Their pathogenicities have not been compared to *A. cassiae.*

ii) Diseases caused by Cercospora *and related species (foliar blights and leaf spots).* Fourteen different *Cercospora* and related species have been described on *Cassia* species (Table 1). Although originally identified as Cercosporas, many have been redisposed in other genera including *Cercosporidium, Phaeoisariopsis, Phaeoramularia* and *Pseudocercospora* (Brown and Morgan-Jones 1976, Cock and Evans 1984). Most cause cream to grey to brown, circular to irregular leaf spots.

Although the host range and distribution of some species is restricted, other species including *Phaeoramularia occidentalis* and *Pseudocercospora nigricans*, are widely distributed on at least 4 *Cassia* species while wide host ranges of *Cercosporidium cassiae* and *Phaeoisariopsis simulata* and the wide distribution of *Pseudocercospora bradburyae* are also of note (Table 1). From limited information available, *P. nigricans* is regarded as the most serious pathogen of this group (Cock and Evans 1984). Severe leaf necrosis of *C. tora* has been reported from Sudan where the pathogen is common.

Cercospora sp., producing brown spots of leaf margins, has been observed on *C. rotundifolia* in Brazil and Colombia (Lenné, personal observations). It is regarded as a minor disease.

iii) Diseases caused by Phomopsis *species (foliar and pod spots; dieback). Phomopsis cassiae* and *Phomopsis* sp. have been recorded mainly as causal agents of foliar and pod spots of a range of *Cassia* species in several different countries (Table 1). *Phomopsis* sp. has been isolated from necrotic lesions on leaves and pods of *C. rotundifolia* in Australia (Davis, personal communication), Brazil and Colombia (Lenné, unpublished records). It is presently regarded as a minor disease.

Phomopsis cassiae has been implicated as the cause of wilt and dieback of *C. alata* in Tanzania (Ebbels and Allen 1979), *C. fistula* in the USA (Farr *et al.* 1989) and *C. occidentalis* in Barbados (Baker and Dale 1948). Further work is needed on the manifestation of this pathogen as wilt and dieback. This is potentially more serious to *C. rotundifolia* than foliar and pod spot.

iv) Diseases caused by rusts. Species of *Endophyllum, Ravenelia, Uredo* and *Uromyces* have been described on *Cassia* species (Table 1). *Endophyllum cassiae*, a short-cycled rust, has been recorded on *C. obtusifolia* in Ghana, Nigeria and Tanzania and on *C. tora* in India, Malaysia and the Philippines (Cock and Evans 1984, Ebbels and Allen 1979, Rangaswanii and Channamma 1970, Singh 1973). Although it is common and widespread on the above hosts, its importance has not been evaluated.

At least 5 *Ravenelia* species, autoecious rusts common on legumes, have been recorded on *Cassia* species (Table 1). Of these, *R. berkeleyii* causes severe blight of leaves, stems and pods of *C. absus* in India, Tanzania and Zambia and *C. fistula* and *C. tora* in India (Cock and Evans 1984, Ebbels and Allen 1979, Rangaswanii and Channamma 1970). No information of the importance of other *Ravenelia* species, all recorded in the Americas and the Caribbean, was found.

Uredo socotrae causes severe leaf necrosis of *C. tora* in Burma (Table 1, Cock and Evans 1984). It has also been recorded on other *Cassia* species in Malaysia. It is possible that *U. socotrae* is the urediniospore stage of *R. berkeleyii* (Cock and Evans 1984). Little is known about other rusts recorded on *Cassia species.*

v) Disc-spot of leaves caused by Pseudoperonospora cassiae. Disc-spot is widespread and serious

on *C. occidentalis* in Ghana, Mauritius, Nigeria, Sierra Leone and Tanzania (Table 1, Cock and Evans 1984, Ebbels and Allen 1979, Orieux and Felix 1968). Symptoms are described as disc-spot in Tanzania (Ebbels and Allen 1979) and brown, water-soaked lesions causing premature leaf fall in Ghana (Cock and Evans 1984). Waterhouse and Brothers (1981) believe that *P. cassiae* occurs in other countries on other *Cassia* species.

vi) Leaf spot caused by Corynespora cassiicola. Although leaf spot caused by *C. cassiicola* has been recorded only on *C. occidentalis* in India and *C. tora* in Pakistan (Table 1), it is an important pathogen of a wide range of crops, particularly in the tropics, and races from one host will attack another (Cock and Evans 1984). Knowledge of the pathogenicity of *P. cassiae* and *C. cassiicola* to *C. rotundifolia* would be of value.

vii) Rhizoctonia *foliar blight.* Severe foliar blight, caused by *Rhizoctonia solani*, has been observed on *C. rotundifolia* in wetter regions of Brazil and Colombia (> 2000 mm mean annual rainfall) (Lenné, unpublished records). Symptoms initiate as small, water-soaked spots which enlarge forming grey necrotic lesions involving part or whole leaflets. Under very humid conditions, webblight symptoms are common and defoliation may occur. Foliar blight was not observed on *C. rotundifolia* in drier regions of Brazil (< 1500 mm mean annual rainfall) such as the cerrados. *Rhizoctonia solani* also causes seedling blight of *C. tora* in the USA (Farr *et al.* 1989).

Less damaging fungal pathogens

i) Anthracnoses. Five *Colletotrichum* species have been recorded on *Cassia* species including *C. rotundifolia. Colletrotrichum capsici* (Syd.) Butler & Bisby has been recorded on *C. occidentalis* in Malaysia (Singh 1973) and *C. tora* in India, Malaysia and Venezuela (IMI); *C. fragariae* causes anthracnose of *C. obtusifolia* in Florida (Howard and Albregts 1973); *C. gloeosporioides* (Penz.) Penz. & Sacc. has been recorded on *C. absus* in Zambia (IMI), *C. alata* in Tanzania (Ebbels and Allen 1979) and Venezuela (IMI), *C. occidentalis* in India (IMI), *C. rotundifolia* in Australia (Davis, personal communication), Brazil and Colombia (Lenné, unpublished records) and *C. tora* in Burma (Rhind and Seth 1945), India (IMI) and Malaysia (Kueh 1976); *C. lindemuthianum* (Sacc. & Magn.) Br. & Cav. has been found on *C. fistula, C. occidentalis* and *C. tora* in India (IMI); while *C. truncatum* (Schw.) Andrus & Moore has been recorded on *C. occidentalis* in India (IMI) and the USA (Gudauskas *et al.* 1977) and *C. rotundifolia* in Colombia (Lenné, unpublished records). *C. truncatum* has been considered as a biological control agent of the weed coffee senna *C. occidentalis* in the USA (Gudauskas *et al.* 1977).

With the exception of *C. fragariae*, these *Colletotrichum* species have wide host ranges and cause a range of diseases including leaf and stem spots, dieback, seedling blight and fruit rot. Both *C. gloeosporioides* and *C. truncatum* produce small rounded grey-cream spots with dark borders on leaves and stems on *C. rotundifolia* in Brazil and Colombia. Observations to date suggest that anthracnose is a minor disease of *C. rotundifolia.*

ii) Tar spot. Three species of *Phyllachora*, the causal genus of tar spot, have been recorded on *Cassia* species. These include: *P. bakeriana* P. Henn. on *C. fistula* in Bermuda (IMI); *P. canafistulae* Stev. & Dalbey on *C. fistula* in Costa Rica, Puerto Rico and the West Indies (Stevenson 1975), Grenada (Baker and Dale 1948), Jamaica (Leather 1967), Trinidad and Tobago (Baker and Dale 1951) and the USA (Farr *et al.* 1989); and *P. cassiicola* S. Ananth. on *C. tora* in India (IMI). No information was found on their importance.

iii) Powdery mildew. Oidium sp. is a widespread pathogen of *Cassia* species. It forms whitish irregular patches on leaf surfaces frequently covering the whole leaf. It has been recorded on *C. fistula* in India (IMI), *C. floribunda* in Australia (Simmonds 1966), India (IMI) and Pakistan (Khan and Kamal 1968), *C. obtusifolia* in Tanzania (Ebbels and Allen 1979), *C. occidentalis* in Bhutan, Cuba, Kenya, Malaysia, Mauritius, Venezuela, Yemen (IMI), India (Rangaswanii and Channamma 1970), Jamaica (Leather 1967), Malawi (Wiehe 1953), Tanzania (Ebbels and Allen 1979), USA (Ishii 1973), *C. sophera* in India (IMI), *C. surattensis* in Pakistan (Khan and Kamal 1968) and on *C. tora* in Cuba, Gambia, Malaysia, Nigeria (IMI) and India (Rangaswanii and Channamma 1970).

Erysiphe polygoni DC. has also been recorded on *Cassia* species including *C. diphylla, C. occidentalis* and *C. tora* in Puerto Rico and the American Virgin Islands (Stevenson 1975) and on *C. occidentalis* in Colombia (Chardon and Toro 1930). No information on the relative importance of the two powdery mildews was found.

Table 1. Damaging and potentially damaging fungal diseases of *Cassia* species

Pathogen	Host range	Distribution	Source
Diseases caused by *Alternaria* species (foliar and seedling blights)			
A. alternata (Fr.) Keissler	*C. fistula*	India	Saxena *et al.* (1981), IMI‡
	C. tora		
A. cassiae Jurair & Khan	*C. fistula*	India	IMI
	C. obtusifolia	USA	Boyette (1988)
	C. occidentalis	USA	
	C. sophera	India	IMI
	C. surattensis	India	
A. tenuissima (Pers.) Wilts.	*C. fistula*	Pakistan	IMI
	C. tora	India	
Diseases caused by *Cercospora* and related species (foliar blights and leaf spots)			
C. canescens Ell. & Mart.	*C. alata*	Cuba	IMI
	C. tora	India	
C. cassiae-occidentalis Yen	*C. occidentalis*	Singapore	IMI
C. cassiocarpa (Sacc.) Chupp	*C. occidentalis*	India	Rangaswanii & Channamma (1970)
		Philippines, Sierra Leone, Venezuela, Zambia	IMI
	C. tora	Venezuela	IMI
C. paulensis P. Henn.	*C. occidentalis*	Colombia	Chardon & Toro (1930)
C. pinnulicola Atk.	*C. nictitans*	USA	Chupp (1953)
	C. occidentalis	Sierra Leone, Sudan	IMI
	C. tora	Cuba, Guinea, India	IMI
Cercospora sp.	*C. grandis*	Trinidad	IMI
	C. rotundifolia	Brazil, Colombia	Lenné (unpubl.)
	C. sophera	Papua New Guinea	IMI
	C. surattensis	Burma	IMI
Cercosporidium cassiae (P. Henn.) Deighton	*C. floribunda*	Tanzania	Riley (1960)
	C. hirsuta	Colombia, Jamaica	IMI, Leather (1967)
	C. macranthera	Brazil	Silveira (1936)
	C. occidentalis	Uganda	IMI
Phaeoisariopsis simulata (Ell. & Ev.) Brown & Morgan-Jones	*C. alata*	Colombia, USA, Venezuela	Chupp (1953)
	C. grandis	Colombia	Chardon & Toro (1930)
	C. hirsuta		
	C. occidentalis	Puerto Rico	Stevenson (1975)
Phaeoramularia occidentalis	*C. fistula*	Argentina, Barbados, Brazil, Colombia, Dominican Republic, India, Philippines, Somalia, South Africa, Trinidad, USA	Chupp (1953)
	C. grandis	Argentina, India, Philippines, Somalia	Chupp (1953)
	C. occidentalis	Argentina	Chupp (1953)
		Barbados	Baker & Dale (1951)
		Bengal, Cuba, Colombia, Dominican Republic, South Africa, USA	IMI
		Grenada	Baker & Dale (1951)
		Puerto Rico, Virgin Islands	Stevenson (1975)
	C. tora	Argentina, Barbados, Brazil, Colombia, India, Philippines, Somalia, South Africa, Trinidad, USA	Chupp (1953)
Pseudocercospora angulata (Chupp & Solheim) Deighton	*C. fistula*	Bangladesh, Burma, Malaysia	IMI
	C. hirsuta	South America, USA	Chupp (1953)

Table 1 continued

Pathogen	Host range	Distribution	Source
P. bradburyae (Young) Deighton	*C. hirsuta*	Barbados, Brazil, Colombia, Dominican Republic, South Africa, USA	Chupp (1953)
		Trinidad & Tobago	Baker & Dale (1951)
P. nigricans (Cke.) Deighton	*C. fistula*	USA	Farr *et al.* (1989)
	C. obtusifolia	India, Philippines	IMI
		USA	Hofmeister & Charudattan (1987)
	C. occidentalis	India, USA, Venezuela	IMI
		Malaysia	Liu (1977)
	C. sophera	India	IMI
	C. tora	India, Japan	Chupp (1953)
		Burma, Cuba, Pakistan, Puerto Rico, Sudan, USA	IMI
		Trinidad & Tobago	Baker & Dale (1951)
P. singaporensis (Yen) Yen	*C. occidentalis*	Singapore	IMI
Pseudocercospora sp.	*C. fistula*	India	IMI
	C. rotundifolia	Colombia	Lenné (unpubl.)
Diseases caused by *Phomopsis* species (foliar and pod spots; dieback)			
P. cassiae Da Camara	*C. alata*	Tanzania, Venezuela	Ebbels & Allen (1979) IMI
	C. fistula	India, USA	IMI, Farr *et al.* (1989)
	C. obtusifolia	Barbados	Norse (1974)
	C. occidentalis	Barbados, Venezuela	Norse (1974), IMI
	C. spectabilis	India	IMI
	C. tora	India, Venezuela, USA	Farr *et al.* (1989)
Phomopsis sp.	*C. alata*	Venezuela	IMI
	C. rotundifolia	Australia	Davis (pers. comm.)
		Brazil, colombia	Lenné (unpubl.)
	C. tora	Cuba	IMI
Diseases caused by rusts			
Endophyllum cassiae (Bresad.) Stevens & Mendiola (syn. *Aecidium cassiae* Bresad.)	*C. obtusifolia*	Ghana, Nigeria, Tanzania	IMI, Ebbels & Allen (1979)
	C. sylvestris	India	Shivalingaradhya (1985)
	C. tora	Sierra Leone	IMI, Singh (1973)
		Malaysia, India	Rangaswanii & Channamma (1970)
Ravenelia berkeleyii Mundk. & Thirum	*C. absus*	India	IMI, Rangaswanii & Channamma (1970)
		Tanzania, Zambia	Ebbels & Allen (1979), IMI
	C. fistula	India	IMI
	C. tora	India	IMI
R. cassicola Atk.	*C. nictitans*	USA	Farr *et al.* (1989)
	C. polyadena	Barbados	Baker & Dale (1951), Norse (1974)
		Trinidad & Tobago	Baker & Dale (1951)
R. indica Berk.	*C. absus*	Venezuela	Kern & Thurston (1944b)
R. mirandensis Kern & Thurston	*C. tora*	Venezuela	Kern & Thurston (1944a)
R. spinulosa Dietel & Holway	*C. biflora*	Mexico	IMI
		Venezuela	IMI, Chardon & Toro (1934)
Ravenelia sp.	*C. polyadena*	Barbados	IMI
Uredo cassiae-occidentalis T.S. Ramakr.	*C. occidentalis*	India	IMI
U. cassiae-rugosae Thurston	*C. rugosa*	Brazil	IMI

Table 1 continued

Pathogen	Host range	Distribution	Source
U. socotrae H. & P. Sydow	*C. pallida*	Malaysia	Singh (1973)
	C. sophera	Malaysia	IMI
	C. tora	Burma	
Uredo sp.	*C. surattensis*	Hong Kong	IMI
Uromyces cassiae-mimosoides Doidge	*C. mimosoides*	South Africa	IMI
Disc-spot			
Pseudoperonospora cassiae Waterhouse & Brothers	*C. occidentalis*	Ghana, Mauritius, Nigeria, Sierra Leone Tanzania	Cock & Evans (1984), Orieux & Felix Ebbels & Allen (1979)
Leaf spot			
Corynespora cassiicola (Berk. & Curt.) Wei	*C. occidentalis*	India	IMI
	C. tora	Pakistan	
Rhizoctonia foliar and seedling blight			
Rhizoctonia solani Kühn	*C. rotundifolia*	Brazil, Colombia	Lenné (unpubl.)
	C. tora	USA	Farr *et al.* (1989)

‡IMI = Unpublished records from the International Mycological Institute

iv) Scab. Scab, caused by *Sphaceloma cassiae* Vogel and *Sphaceloma* sp., have been found on *C. splendida* in Brazil (Bitancourt and Jenkins 1949) and on *C. obtusifolia* in Zimbabwe (Rothwell 1983), respectively. Although scab is recognized as a serious disease of other legumes in the tropics (Allen 1983), no information of its importance to *Cassia* species was found.

v) False rust. Synchytrium cassiae Lingappa has been reported on *C. pumila* in India causing marked hypertrophy of shoots (IMI, Cock and Evans 1984). The host range of this pathogen is unknown.

vi) Root rot. Six different root rotting fungi have been recorded on *Cassia* species in tropical regions. These include *Botryodiplodia theobromae* Pat. on *C. fistula, C. spectabilis* and *C. tora* in India (IMI); *Macrophomina phaseolina* (Tassi) Goid on *C. floribunda* Tanzania (Riley 1960) and *C. tora* in India (IMI); *Ophiobolus fulgidus* (Cke. & Peck) Sacc. on *C. occidentalis* in Cuba (IMI); *Phellinus noxius* (Corner) G. Cunn. on *C. grandis* in Papua New Guinea (Shaw 1985); *Thielaviostilbe* sp. on *C. fruticosa*; and *Xylaria polymorpha* (St. Amans) Grev. on *C. spectabilis*, both in Sierra Leone (IMI). All of these pathogens are widespread, have wide host ranges and may cause serious diseases of tropical crops. But, their importance to *Cassia* species has not been documented.

vii) Stem canker, wilt, dieback and pink disease. Two species of *Hypoxylon* cause stem cankers of *Casia* species in Sierra Leone — *H. rubiginosum* (Fr.) Fr. has been recorded on *C. fistula* and *C. fruticosa* while *H. stygium* (Lév.) Sacc. has been recorded on *C. fruticosa* only (IMI). *Diplodia* sp. has been recorded on *C. fistula* and *C. spectabilis* in India while *Nectria dealbata* Berk. & Br. has been recorded on *C. fruticosa* in Sierra Leone causing dieback (IMI). No further information on these diseases could be found.

Cephalosporium sp. was isolated from wilted *C. surattensis* in the USA (Trujillo and Obrero 1976). It is apparently restricted to its host and is being considered as a potential biological control agent.

Pink disease, caused by *Phanerochaeta salmonicolor* (Berk. & Br.) Jülich, and manifest as leaf and twig blight, has been recorded on *C. fistula* and *C. fruticosa* in Australia (Simmonds 1966) and *C. floribunda* in Mauritius (Orieux and Felix 1968, Wiehe 1948) and Tanzania (Riley 1960). It is unlikely to affect *C. rotundifolia* in Australia as it is serious only in humid environments.

Other fungal pathogens isolated from Cassia *species*

A large group of fungi causing leaf spots, including 21 genera and at least 41 species have been recorded on *Cassia* species. Because no further information could be found, no opinion can be given regarding their potential importance to *C. rotundifolia*. Only one pathogen, *Phyllosticta* sp. causing a minor leaf spot, has been recorded on *C. rotundifolia* itself. A list of these pathogens is included for completeness.

Ascochyta cassiae P. Henn. — *C. occidentalis* — India (IMI); *Cochliobolus lunatus* Nelson & Haasis — *C. surattensis, C. tora* — India (IMI); *C. pallescens* (Tsuda & Ueyama) Sivan. — *C. occidentalis, C. tora* — India (IMI); *C. spicifera* Nelson — *C. fistula* — Pakistan (IMI); *C. verruculosus* (Tsuda & Ueyama) Sivan. — *C. fistula* — India (IMI); *Coniothryium fuckelii* Sacc. — *C. occidentalis* — Venezuela, *C. spectabilis* — India, *C. surattensis* — Pakistan (IMI); *Curvularia affinis* Boedijn — *C. occidentalis* — India (IMI); *C. clavata* B.L. Jain — *C. fistula* — India (IMI); *Dendryphiella vinosa* (Berk. & Curt.) Reisinger — *C. fistula, C. occidentalis, C. tora* — India, *C. fruticosa* — Sierra Leone (IMI); *Kabatiella nigricans* (Atk. & Edgerton) Karak. — *C. fistula* — India (Mitra *et al.* 1984); *Khuskia oryzae* Hudson — *C. tora* — India (IMI); *Leptosphaeria* sp. — *C. fistula* — Malaysia, *C. hirsuta* — Guinea, *C. tora* — Cuba (IMI); *Leptosphaerulina trifolii* (Rostrup) Petrak — *C. fistula, C. tora* — India (IMI); *Mycosphaerella cassiae* Stevens — *C. spectabilis* — Cuba (IMI); *M. guineensis* Kranz — *C. alata* — Guinea, Venezuela (IMI), Tanzania (Ebbels and Allen 1979); *Myrothecium roridium* Fr. — *C. obtusifolia, C. surattensis* — India (IMI, Tripathi and Udit 1986); *Periconia byssoides* Pers. — *C. fruticosa* — Sierra Leone (IMI); *Pestalotiopsis adusta* (Ell. & Ev.) Steyaert — *C. fistula* — India (IMI); *P. japonica* (Syd.) Steyaert — *C. tora* India (IMI); *P. versicolor* (Speg.) Steyaert — *C. fistula* — India (IMI); *Pestalotiopsis* sp. — *C. absus* — India (IMI); *Phoma exigua* Desm. — *C. fistula* — India (IMI); *P. macrostoma* Mont. — *C. occidentalis* — Venezuela, *C. spectabilis* — India (IMI); *Phoma* sp. — *C. fistula* — India (IMI); *Phyllactinia dalbergiae* Pirozynski — *C. fistula* — India (IMI); *Phyllosticta amaltasia* Chardon & Toro — *C. fistula* — India (IMI); *P. cassiae* Choudury — *C. tora* — Cuba, India, Venezuela (IMI); *P. cassiae-occidentalis* Vasant Rao — *C. occidentalis* — India (IMI); *Phyllosticta* sp. — *C. rotundifolia* — Zimbabwe (Rothwell 1983); *Pleospora helvetica* Niessl — *C. spectabilis* — India (IMI); *Septoria cassiicola* Kell. & Swingle — *C. fistula* — India (IMI); *Septoria* sp. — *C. tora* — Cuba (IMI); *Stagnospora* sp. — *C. alata* — Venezuela (IMI), *C. fistula* — Pakistan (Ishaque and Talukdar 1967); *Stenella cassiae* Abbasi & Shukla — *C. fistula* — India (IMI); *S. chandleri* (Hansf.) Singh & Kamal — *C. fistula* — India (IMI); *Stenella* sp. — *C. grandis* — Cuba (IMI); *Volutella cassiicola* Vasant Rao — *C. occidentalis* — India (IMI); *V. colletotrichoides* Chilton — *C. sophera* — India (IMI).

Bacterial diseases

Two bacteria have been recorded on *Cassia* species (Bradbury 1986). *Xanthomonas campestris* (Pammel) Dowson pv. *cassiae* has been found causing blight of *C. occidentalis* and *C. tora* in India. Although its importance to *Cassia* species has not been documented, it causes a serious seedling blight of chickpeas in India (Allen 1983). *Pseudomonas solanacearum* (Smith) Smith causes wilt of a large number of tropical legumes and is distributed worldwide. It has been recorded on *C. mimosoides* and *C. spectabilis*. No further information was found.

Viruses

A range of viruses including bromo-, carla-, potex- and potyviruses have been recorded on *Cassia* species (Table 2). Cassia Mild Mosaic Virus (CMMV), a carlavirus, was first recorded on *C. sylvestris*, native to the Brazilian cerrados, and later found on *C. macranthera*, also native to Brazil, *C. obtusifolia* and *C. occidentalis* (Lin *et al.* 1979). It causes vein chlorosis, necrosis and mild leaf mosaic of *C. sylvestris* but causes severe dieback of *C. macranthera*, commonly used as an ornamental street tree in Brazil (Lin *et al.* 1980). Although CMMV is widespread in Brazil, it has not been recorded elsewhere and it does not appear to be seed-borne (Lin *et al.* 1979).

Two different viruses have been given similar names related to their manifestation as yellow leaf blotches on their hosts (Table 2). Cassia Yellow Blotches Virus (CYBVa), a potyvirus, first isolated from *C. hoffmannseggii*, native to the

Table 2. Viruses recorded on *Cassia* species

Virus	Host range	Distribution	Source
Cassia Mosaic Virus	*C. occidentalis* *C. tora*	Papua New Guinea	Velsen (1961)
Cassia Mild Mosaic Virus (carlavirus)	*C. macranthera* *C. obtusifolia* *C. occidentalis* *C. sylvestris* *C. tora*	Brazil	Lin *et al.* (1979) Lin *et al.* (1980)
Cassia Yellow Blotches Virus (potyvirus)	*C. hoffmannseggii* *C. obtusifolia* *C. occidentalis*	Brazil	Paguio & Kitajima (1981)
Cassia Yellow Blotch Virus (bromovirus)	*C. floribunda* *C. hirsuta* *C. occidentalis* *C. pleurocarpa*	Australia	Dale *et al.* (1984)
Negro Coffee Mosaic Virus (potexvirus)	*C. occidentalis*	India	Misra *et al.* (1984), Verma & Niazi (1974)

Brazilian cerrados, causes chlorotic blotches and leaf deformation on this species as well as *C. obtusifolia* and *C. occidentalis* (Paguio and Kitajama 1981). It has not been recorded outside Brazil.

Cassia Yellow Blotch Virus (CYCVb), a bromovirus, was recently found on the Australian endemic *C. pleurocarpa* in western Queensland (Dale *et al.* 1984). Affected leaves showed vivid yellow blotches. *C. floribunda, C. hirsuta* and *C. occidentalis* were infected by the virus in glasshouse inoculation studies. Unfortunately, *C. rotundifolia* was not included in these tests. Although CYBVb has only been recorded on *C. pleurocarpa* in a very restricted area of Queensland, the legume is widely distributed throughout drier regions of Queensland and Western Australia and surveys are recommended to determine the distribution of the virus. It is also possible that other Australian endemic *Cassia* species may host CYBVb.

Negro Coffee Virus (NCMV), a potexvirus, has been recorded on *C. occidentalis* in India (Verma and Niazi 1974, Misra *et al.* 1984). NCMV causes leaf chlorosis and mottling, vein banding and internode shortening (Misra *et al.* 1984). It is similar to Tobacco Mosaic Virus but apparently restricted to *C. occidentalis* (Verma and Niazi 1974).

Cassia Mosaic Virus (CMV) has been recorded on *C. tora* in Papua New Guinea (Velsen 1961). As the virus has not been characterized, it is not possible to determine if it is different to CMMV or NCMV.

From glasshouse inoculation studies, *C. occidentalis* has been found to host 6 viruses. These include: Abaca Mosaic Virus (Tiongo and Celino 1972), Cucumber Mosaic Virus (Inouye *et al.* 1982), the orchid viruses Cymbidium Mosaic Virus and Odontoglossum Ring Spot Virus (Chagas *et al.* 1977, Ganapathi *et al.* 1985), Soyabean Mosaic Virus (Galvez 1974) and White Clover Mosaic Virus (Joshi *et al.* 1981). In addition, *C. obtusifolia* hosts Tobacco Etch Virus (Demski 1979) while *C. tora* hosts Southern Bean Mosaic (Singh and Singh 1973) and Tobacco Etch Virus (DeBrot 1976).

Diseases caused by nematodes

Species of cyst nematode (*Heterodera* sp.), lesion nematode (*Pratylenchus brachyurus, P. coffeae* and *P. pratensis*) and root-knot nematode (*Meloidogyne arenaria, M. javanica* and *M. incognita*) as well as *Helicotylenchus* sp. and *Rotylenchus reniformis* have been reported on *Cassia* species throughout the tropics (Table 3). As for many of the diseases listed above, information is restricted to host range and distribution. No information was found concerning the relative importance of these nematodes.

Table 3. Nematodes recorded on *Cassia* species

Nematodes	Host range	Distribution	Source
CYST NEMATODE			
Heterodera sp.	*Cassia* sp.	USA	Riggs & Hamblen (1962)
LESION NEMATODE			
Pratylechus brachyurus (Godfrey) Filipjev & Stekhoven	*C. absus* *C. hirsuta*	West Africa	Luc & Guiran (1960)
P. coffeae (Zimmerman) Goodey	*C. mimosoides* *C. tora*	? India	Fluiter & Mulholland (1941), Souza & Kasiviswanathan (1969)
P. pratensis Filipjev	*C. mimosoides* *C. occidentalis*	?	Goodey (1940)
ROOT — KNOT NEMATODE			
Meloidogyne arenaria (Neal) Chitwood	*C. occidentalis* *C. tora*	USA	Machmer (1951)
M. javanica Chitwood	*C. absus*	Zimbabwe	Martin (1954)
	C. alata	Brazil	Freire & Ponte (1976)
	C. mimosoides	Australia	Colbran (1958)
	C. obtusifolia	Brazil	Moraes *et al.* (1972)
	C. sophera	India	Bhatti *et al.* (1974)
	C. tora	India	Nirula & Kumar (1963)
M. incognita (Kofoid & White) Chitwood	*C. absus* *C. hirsuta*	West Africa	Luc & Guiran (1960)
	C. mimosoides	West Africa, Australia	Luc & Guiran (1960), Colbran (1958)
	C. occidentalis	West Africa	Luc & Guiran (1960)
	C. tora	India	Alam (1975)
Meloidogyne sp.	*C. artemesoides*	USA	Anonymous (1935)
	C. floribunda	USA	Buhrer (1938)
	C. mimosoides	India	Barber (1901)
	C. occidentalis	USA	Godfrey (1940)
	C. tora	USA	Stanton & Rizo (1988)
OTHER NEMATODES			
Helicotylenchus sp.	*C. hirsuta*	West Africa	Luc & Guiran (1960)
Rotylenchus reniformis Linford & Oliveira	*C. tora*	USA	Steiner (1949)

Biological control of *Cassia* weeds — implications for *Cassia rotundifolia*

Lack of effective, low-cost, non-chemical weed control measures has stimulated development of biological control agents such as mycoherbicides particularly in the USA. Two mycoherbicides have already been commercialized and are being used in the southernmost USA. These are Collego™, a formulation of *Celletotrichum gloeosporioides* to control northern jointvetch *Aeschynomene virginica*, and DeVine™, a formulation of *Phytophthora citrophthora* for control of stranglervine in citrus plantations (Templeton 1988).

Five *Cassia* species reviewed in this paper are widespread pantropical weeds. Three are regarded as serious: *C. obtusifolia*, sicklepod, is a serious weed of peanuts and soyabeans in the southern USA (Cock and Evans 1984, Walker and Boyette 1985); *C. occidentalis*, coffee senna, is a serious weed of cotton in the southern USA (Walker and Boyette 1985); while *C. tora*, foetid cassia, is regarded as the most serious weed of pastures in South-east Asia and the south-west Pacific region including Fiji, Solomon Islands, Western Samoa and Vanuatu (Cock and Evans 1984).

A formulation of *Alternaria cassiae*, CASST™, will be released soon in the USA for control of sicklepod and coffee senna in cotton, peanut and soyabean plantings (Bannon 1988). Although CASST™ is regarded as a particularly valuable mycoherbicide because its host range is restricted to the above weeds and *Crotalaria spectabilis*, host range studies within the genus *Cassia* were restricted to the target weed species

only (Walker 1982). The pathogenicity of *A. cassiae to C. rotundifolia* is unknown.

Other pathogens of *Cassia* species being considered as biological control agents of *C. obtusifolia, C. occidentalis* and *C. tora* include *Pseudocercospora nigricans* (Cock and Evans 1984, Hofmeister and Charudattan 1987), *Colletotrichum truncatum* (Gudauskas *et al.* 1977), *Pseudoperonospora cassiae* and *Ravenelia berkeleyii* (Cock and Evans 1984). Of particual note, *P. nigricans, P. cassiae* and *R. berkeleyii* are being evaluated by the Commonwealth Institute of Biological Control at Silwood Park, England for development as mycoherbicides for control of *C. tora* in pastures in South-east Asia and the south-western Pacific (Cock and Evans 1984). It is strongly recommended that the reaction of cv. Wynn to these pathogens be determined as soon as possible.

Research recommendations

Although information on the relative importance of diseases of *Cassia* species is limited, several diseases have already proven damaging to their hosts and others are regarded as potentially damaging. These include fungal pathogens *Alternaria cassiae, Corynespora cassiicola, Phomopsis cassiae, Pseudocercospora nigricans, Pseudoperonospora cassiae* and *Ravenelia berkeleyii* and viruses Cassia Mild Mosaic, Cassia Yellow Blotches and Cassia Yellow Blotch. Although the majority of these diseases have not been reported in Australia, their *Cassia* hosts do occur in Australia.

It is strongly recommended that the reaction of *C. rotundifolia* cv. Wynn to these diseases should be ascertained as soon as possible. This could be relatively easily achieved for the fungal pathogens by collaborating with one or several of the laboratories in the USA and England presently evaluating the potential of these pathogens as mycoherbicides. Cultivar Wynn could be included in their trials outside Australia thus eliminating the risk of introducing these pathogens to Australia for testing. The reaction of cv. Wynn to Cassia Yellow Blotch Virus, native to Australia, should also be tested while collaboration with virologists at the University of Brasilia should enable cv. Wynn to be tested against Cassia Mild Mottle and Cassia Yellow Blotches viruses.

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