TEMPORAL OCCURRENCE PATTERN OF INSECT PESTS AND FUNGAL PATHOGENS IN YOUNG TASMANIAN PLANTATIONS OF *EUCALYPTUS GLOBULUS* LABILL. AND *E. NITENS* MAIDEN

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(with four text-figures, four plates and two tables)

de Little, D.W., Foster, S.D. & Hingston, T.L. 2008 (28:xi): Temporal occurrence pattern of insect pests and fungal pathogens in young Tasmanian plantations of *Eucalyptus globulus* Labill. and *E. nitens* Maiden. *Papers and Proceedings of the Royal Society of Tasmania* 142(2): 61–70. https://doi.org/10.26749/rstpp.142.2.61 ISSN 0080-4703. Forest Health Consultant, PO Box 2009, Lower Sandy Bay, Tasmania 7005, Australia (DWdL*); Tasmanian Institute for Agricultural Research, New Town Research Laboratories, 13 St Johns Avenue, New Town, Tasmania 7008, Australia (SDF); 2 Laurel Place, Ulverstone, Tasmania 7315, Australia (TLH). * Author for correspondence. Email: dde64113@ bigpond.net.au

The occurrence and distribution with respect to plantation age, of insect pests and fungal pathogens were studied over a five-year period in Tasmanian plantations of the native eucalypt, *Eucalyptus globulus* Labill., and the introduced *E. nitens* Maiden. A total of 45 taxa of pests and pathogens were identified either by their presence, or by their symptoms, from 289 plantation visits distributed in the north and southeast of the island. Thirty-five taxa were identified on each plantation species. The three taxa, Chrysomelinae, *Mycosphaerella* spp., and *Mnesampela privata* were the three most commonly encountered taxa on each host eucalypt species. Other commonly encountered taxa were *Acrocercops laciniella*, *Gonipterus scutellatus*, *Phaeothyrolium microthyrioides*, and *Uraba lugens*. Some taxa showed a preference for one or other host eucalypt species while other taxa showed no preference. Some taxa preferred younger plantations, while others were more abundant in older plantations. This plantation age-linked distribution is discussed in relation to foliage phase change in the two host eucalypt species.
Key Words: insect pests, fungal pathogens, eucalypt plantations, Tasmania, *Eucalyptus nitens, Eucalyptus globulus*.

INTRODUCTION

The establishment of eucalypt plantations began in Tasmania in the late 1970s as an alternative source of fibre and solid wood to native forests (Tibbits 1986). After experimentation with several species, the two main species selected for plantation establishment were the native Tasmanian species, *Eucalyptus globulus* Labill., Tasmanian Blue Gum, and the mainland Australian species *Eucalyptus nitens* Maiden, Shining Gum, a native of Victoria and New South Wales. Plantation establishment with these two species has expanded to the point where there are now in excess of 150 000 ha in Tasmania (National Forest Inventory 2005). Harvesting of these plantations commenced in the 1990s and many plantations are now in their second rotation.

Land available for plantation establishment in Tasmania lies between sea level and about 700 m elevation in regions that receive a regular rainfall of greater than 600 mm per annum. *E. globulus* is less cold hardy than *E. nitens* and it is therefore generally established in warmer sites where heavy frost does not occur. As a Tasmanian native tree species it could be expected that *E. globulus* plantations would be attacked by the insect pests and fungal pathogens that attack the species in native regrowth forests. Outbreaks of pests and diseases in Tasmanian eucalypt plantations led to the development of plantation health surveillance programs in the late 1990s (de Little 2002, Stone *et al.* 2003, Carnegie, 2007a, b, 2008).

Both eucalypt species exhibit strong heterophylly with foliage phase change occurring in the early years of the plantation cycle. Observations on pest and disease outbreaks suggested that some might favour juvenile foliage or plantations before canopy closure, while others favoured older plantations post canopy closure and with adult foliage. Predictable temporal variations in pest and disease occurrence could enable more efficient monitoring programs.

The current study reports on insect pests and fungal pathogens encountered in Tasmanian *E. globulus* and *E. nitens* plantations managed by Gunns Limited (formerly North Forest Products) during a five-year plantation health surveillance program between 1998 and 2002.

METHODS

Survey methods

The locations of plantations surveyed on the main island of Tasmania are shown in figure 1.

Plantations were neither thinned nor pruned and typically varied in size from about 10–100 ha with trees planted at a spacing of approximately 3 m^2, giving approximately 1100 trees per ha. Plantation age varied from 1–21 years old. Each plantation visited was surveyed by driving as much as was possible of the perimeter and access roads and also by walking at least three widely spaced transects into the plantation perpendicular to the access road. Length of transect walked was determined by the rate of acquisition of new pest and disease information for the plantation but rarely exceeded 100 m.

Identification methods

Pest and disease organisms were identified by visual detection of their direct presence in association with plantation trees and/or through health disorder symptoms observed on the trees. Where it was not possible to identify causal organisms directly in the field, samples and photographs of the organism and/or its damage symptoms were collected. Samples were maintained in cool storage, and forwarded to relevant experts for identification or compared with descriptions and figures

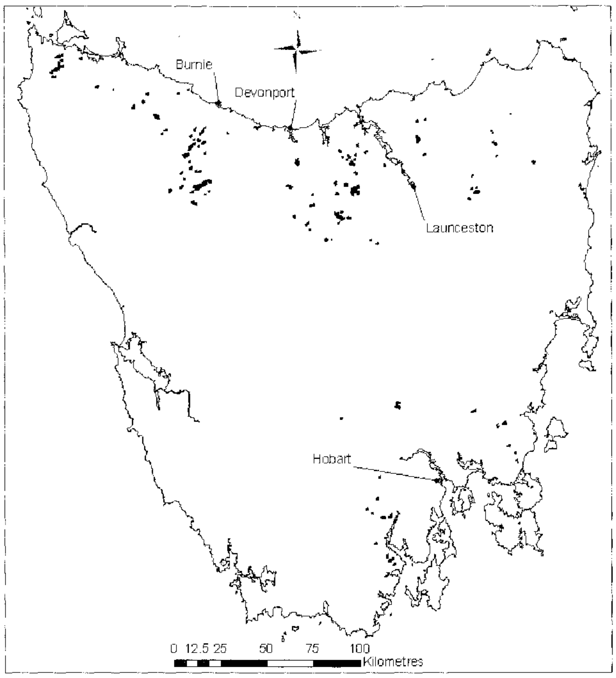


FIG. 1 — Location of plantations within main island of Tasmania.

TABLE 1
Numbers of visits to each age-class of *Eucalyptus globulus* and *E. nitens* plantations

Plantation age-class (yrs)	Total visits	*E. globulus* visits	*E. nitens* visits
1	46	23	23
2	75	30	45
3	47	17	30
4	32	15	17
5	25	5	20
6	19	11	8
7	17	9	8
8	8	3	5
9	6	4	2
10	3	1	2
11	7	1	6
13	1	–	1
15	2	–	2
21	1	1	–
Total	289	120	169

in the relevant literature (Elliott & de Little 1984, Elliott *et al.* 1998, Keane 2000). In most cases causal organisms were identified to species level, but where this was not possible, identification was to genus, sub-family or family level.

Analysis of data

Each pest or pathogen taxon was analysed separately using log-linear models (Venables & Ripley 2002, Agresti 1996) for explaining variation in the number of plantations with damage. Species, year and their interaction were used as possible explanatory variables in the model. Those terms not significant at the 5% level were removed from the model. A goodness-of-fit test is available for these models. This tests the null hypothesis that the model provides an adequate description of the data, a high p-value in this test indicating that there is no evidence to reject this hypothesis.

This type of model is affected adversely by year and species combinations that have extremely low presence (often zero). For this reason these combinations are excluded from the analysis. This completely excludes some pest/pathogen taxa and some taxa by year combinations. When appropriate, these low values can still be plotted with the results from the formal analysis, but they are not taken into account when interpreting the results.

The data set contained several plantations (approximately 12%) that were sampled in more than one year. They were treated as separate plantation sample events for the purpose of analysis.

RESULTS

Description of plantations

A total of 289 plantation visits occurred over the five years that the survey was carried out. The age distribution of these plantations is shown in table 1. Thirty-one plantations were visited in two separate years during the survey period, and three plantations were visited in three separate years during the survey period.

Plantations ranged in altitude between 10 and 730 m above sea level. Annual precipitation varied between approximately 800 and 2000 mm per annum.

Both *E. nitens* and *E. globulus* exhibit heterophylly, undergoing a change in leaf morphology from juvenile to adult foliage as trees age. The rate of transition from juvenile to adult foliage is presented in figure 2. The general pattern appears to be similar for both *E. nitens* and *E. globulus* plantations but not equivalent ($p < 0.001$). It appears that the rate of reduction in purely juvenile plantations is similar for both species but the transition rate from mixed plantations to adult plantations is greater for *E. globulus.*

Pests and pathogens

Twenty-eight taxa (family to species level) of insect pests and 21 fungal pathogens were identified in the plantations surveyed. These were grouped into insect defoliators (13), insect sap-suckers (8), insect borers (4), insect leaf miners (2), insect gall-formers (1), fungal leaf diseases (17), fungal shoot diseases (1), fungal stem cankers (2) and fungal root diseases (1). Full details are given in table 2.

Frequency of occurrence varied greatly between pest and pathogen taxa. Some of the pest and pathogen occurrences were relatively evenly distributed between *E. nitens* and *E. globulus.* Several appeared to favour either one or other host species, e.g., *Ctenarytaina eucalypti* (Maskell, 1890), *Ophelimus* sp. and *Sonderhenia eucalypticola* (A.R. Davis) H.J. Swart & J. Walker on *E. globulus,* and *Armillaria* sp., *Cadmus australis* (Boisduval, 1835) and *Heteronyx* sp. on *E. nitens.*

The criteria described in the Methods section for analysis of pest by species by year combinations, allowed four log-linear model analyses to be carried out for four insect defoliators (Chrysomelinae, *Mnesampela privata* Guenee, 1857, *Uraba*

TABLE 2
Taxa of insect pests and fungal pathogens identified on *Eucalyptus globulus* and *E. nitens* plantations

Taxon	Type	Damage type	Total records	*E. globulus* records	*E. nitens* records
Acrocercops laciniella (Meyrick, 1880)	Insect	Leaf miner	52	23	29
Anoplognathus suturalis Boisduval, 1835	Insect	Defoliator	2	–	2
Armillaria sp.	Fungus	Root disease	15	1	14
Aulographina eucalypti (Cooke & Mass.) Arx & E. Müll.	Fungus	Leaf disease	2	1	1
Botryosphaeria dothidea (Mougeot ex. EM Fries) Cesati & de Notaris	Fungus	Stem canker	1	–	1
Botryosphaeria eucalyptorum Crous, H. Smith & M.J. Wingf.	Fungus	Leaf disease	2	2	–
Botrytis cinerea Pers.	Fungus	Shoot disease	1	1	–
Cadmus australis (Boisduval, 1835)	Insect	Defoliator	12	–	12
Cardiaspina spinifera (Froggatt, 1923)	Insect	Sap sucker	3	1	2
Cardiaspina squamula Taylor, 1962	Insect	Sap sucker	1	–	1
Chrysomelinae (*Paropsis* spp., *Paropsisterna* spp., *Trachymela* spp.)	Insect	Defoliator	110	36	74
Coreidae (*Amorbus obscuricornis* (Westwood, 1842) & *Gelonus tasmanicus* (Le Guillou, 1841))	Insect	Sap sucker	21	1	20
Cryptosporiopsis eucalypti Sankaran & B. Sutton	Fungus	Stem canker	3	–	3
Ctenarytaina eucalypti (Maskell, 1890)	Insect	Sap sucker	15	10	5
Cylindrotrichum sp.	Fungus	Leaf disease	2	1	1
Doratifera pinguis (Walker, 1855)	Insect	Defoliator	1	1	–
Eriococcus confusus Maskell, 1892	Insect	Sap sucker	7	–	7
Eriococcus irregularis Froggatt, 1921	Insect	Sap sucker	1	–	1
Fairmaniella leprosa (Fairm.) Petr. & Syd.	Fungus	Leaf disease	1	–	1
Glycaspis sp.	Insect	Sap sucker	4	3	1
Gonipterus scutellatus Gyllenhal, 1833	Insect	Defoliator	28	26	3
Hesthesis cingulata (Kirby, 1818)	Insect	Borer	3	3	–
Heteronyx spp.	Insect	Defoliator	23	2	21
Hyalinaspis subfasciata (Erichson, 1842)	Insect	Sap sucker	1	–	1
Lamprima aurata Latreille, 1817	Insect	Defoliator	1	–	1
Microsphaeropsis sp.	Fungus	Leaf Disease	1	–	1
Mnesampela privata (Guenée, 1857)	Insect	Defoliator	75	25	50
Mycosphaerella spp.	Fungus	Leaf disease	75	38	37
Myllorhinus dentiferus (Boheman 1858)	Insect	Borer	2	2	–
Ophelimus sp.	Insect	Gall former	14	14	–
Opodiphthera helena (White, 1843)	Insect	Defoliator	1	1	–
Paralaea beggaria (Guenée, 1857)	Insect	Defoliator	2	–	2
Pergidae (*Perga affinis insularis* Riek, 1961 & *Pseudoperga lewisii* (Westwood, 1837))	Insect	Defoliator	3	2	1
Kirramyces eucalypti (Cooke and Massee) J. Walker, B. Sutton & Pascoe	Fungus	Leaf disease	22	3	19
Phaeothyriolum microthyrioides (G. Winter) H.J. Swart	Fungus	Leaf disease	51	9	42
Phoracantha sp.	Insect	Borer	3	1	2
Phylacteophaga sp.	Insect	Leaf miner	1	1	–
Pseudocercospora eucalyptorum Crous, M.J. Wingf. & Marasas	Fungus	Leaf disease	14	4	10
Readeriella mirabilis Syd. & P. Syd.	Fungus	Leaf disease	1	1	–
Rhadinosomus lacordairei Pascoe, 1870	Insect	Borer	2	–	2
Sonderhenia eucalypticola (A.R. Davis) H.J. Swart & J. Walker	Fungus	Leaf disease	13	13	–
Sonderhenia eucalyptorum (Hansf.) H.J. Swart & J. Walker	Fungus	Leaf disease	4	4	–
Thyrinula eucalypti (Cooke & Massee) H.J. Swart*	Fungus	Leaf disease	7	3	4
Tortricidae	Insect	Defoliator	12	10	2
Uraba lugens Walker, 1863	Insect	Defoliator	34	17	17

* *Thyrinula eucalypti* is the anamorph of *Aulographina eucalypti*.

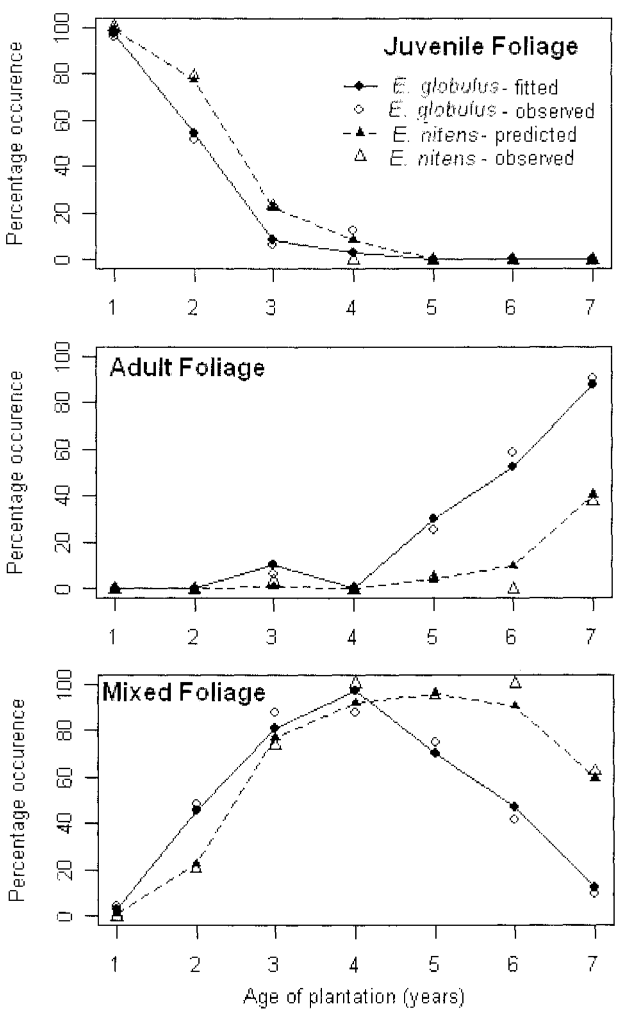


FIG. 2 — Percentage occurrence of plantation foliage types of Eucalyptus globulus *and* E. nitens *at ages from 1–7 years (p=0.610).*

lugens Walker, 1863 and *Gonipterus scutellatus* Gyllenhal, 1833), one insect leaf miner, *Acrocercops laciniella* (Meyrick, 1880), and two fungal leaf diseases (*Mycosphaerella* spp. and *Phaeothyrolium microthyrioides* (G. Winter) H.J. Swart).

Insect defoliators

The most commonly recorded pest taxon was the defoliating Chrysomelinae, a sub-family of leaf beetles (Chrysomelidae) (pl.1A) containing about 36 eucalypt-defoliating species in Tasmania (de Little 1989), of which *Paropsisterna bimaculata* (Olivier, 1807) and *P. agricola* (Chapuis, 1877) are the most common species. Chrysomelinae are generally only present on foliage during the warmer months; however, their presence in plantations was identified by their characteristic scalloping defoliation pattern on leaves that can be recognised at any time of the year (Greaves 1966, de Little 1983). Chrysomelinae were recorded throughout the entire spatial and altitudinal range of plantations. Presence of Chrysomelinae was recorded in both *E. globulus* and *E. nitens* plantations and there was no evidence of preference for one species of eucalypt over another. There was an age effect on the number of plantations with Chrysomelinae damage ($p<0.001$). Young plantations appeared less susceptible than plantations about three years of age and older (fig. 3).

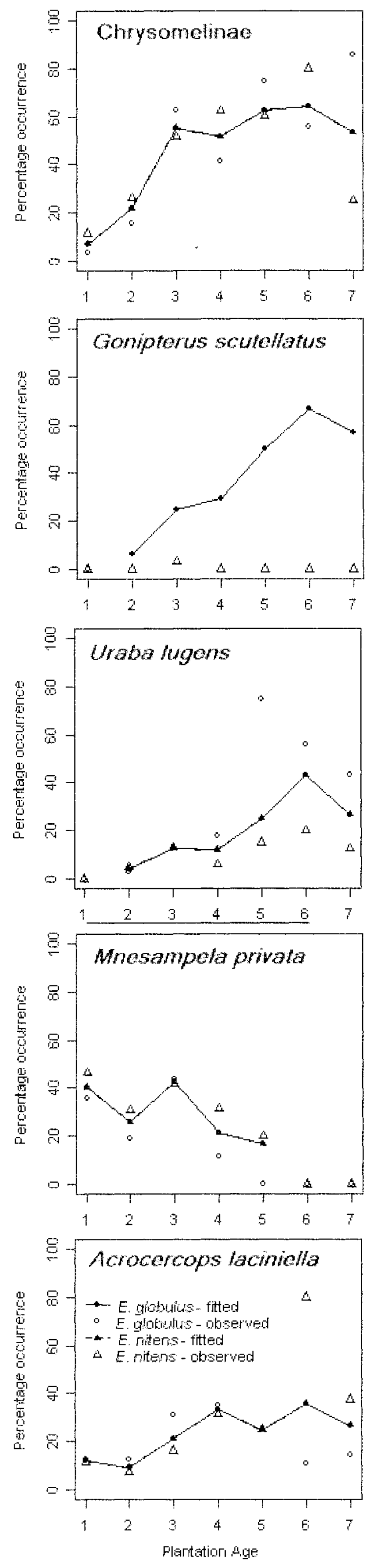


FIG. 3 — Percentage of plantations of Eucalyptus globulus *and* E. nitens *with symptoms of damage caused by Insect Defoliators and Insect Leaf Miners in age classes from 1–7 years (p>0.100).*

The second most commonly recorded insect pest was *Mnesampela privata* (Autumn Gum Moth) (pl. 1B). Presence of this pest was detected by occurrence of eggs or egg cases, larvae, or characteristic webbing and defoliation patterns on leaves (Steinbauer *et al.* 2001). *M. privata* did not prefer one host species over another but the age of the plantation did affect the incidence (p=0.037). The profile of incidence over time indicates that young plantations have higher incidence than older ones (fig. 3). This finding is consistent with the observation that *M. privata* only attacks juvenile foliage (Steinbauer 2002). *M. privata* was recorded throughout the entire spatial and altitudinal range of plantations.

Other commonly recorded insect defoliators were *Uraba lugens* (Gum-leaf Skeletoniser) and *Gonipterus scutellatus* (Eucalypt Snout Weevil) (pl. 1C, D). Presence of both species changed with plantation age (p=0.002 and p=0.02 respectively). It was possible to assess the preference of *U. lugens* to plantation type. This test indicated that there is evidence of preference (p = 0.029). There were insufficient data on *E. nitens* to perform a similar test for *G. scutellatus* (fig. 3).

Less commonly recorded insect defoliators were *Heteronyx* spp (Cockchafers), *Cadmus australis* (Boisduval, 1835) and Tortricidae (Leaf-rollers) (pl. 1E, F, G).

Insect sap-suckers

The most commonly occurring taxon was Coreidae (pl. 2A), identified by the characteristic damage symptoms of wilted or pruned young shoots. This damage is caused by two species, *Amorbus obscuricornis* (Westwood, 1842), Gum-tree Bug, and *Gelonus tasmanicus* (Le Guillou, 1841), Tasmanian Gelonus Bug. Another commonly encountered taxon on very young trees was *Ctenarytaina eucalypti,* Bluegum psyllid (pl. 2B).

Insect borers

None of the four insect borers that were encountered was common or widespread.

Insect leaf miners

Acrocercops laciniella (Blackbutt Leaf-miner) (pl. 2C) was very commonly encountered (mainly in the north of the island) on both eucalypt species. It was recognised by the characteristic "blister" caused by larvae feeding under the leaf epidermis and changed in presence (p=0.028) with increase of plantation age (fig. 3). It appeared to show no preference for either host species.

Insect gall formers

Ophelimus sp. (Blue-gum Chalcid) was encountered only on *E. globulus* in a restricted area in the central north of the island. It was recognised by the characteristic galls formed on young shoots (pl. 2D) that led to twisted and distorted trunks and branches in older trees.

Fungal leaf diseases

The most commonly encountered fungal leaf disease was "Crinkle Leaf" caused by *Mycosphaerella* spp. (pl. 3A). *E. globulus* plantations were more susceptible to attack by *Mycosphaerella* than *E. nitens* plantations (p=0.007). Both types of plantations exhibited a significant (p<0.001) change in incidence over time. Presence appeared to peak in 3–5-year-old plantations, coinciding with maximum quantities of juvenile foliage and the onset of canopy closure and the transition to adult foliage (fig. 4). Carnegie (2007b) observed infection of *E. globulus* subsp. *maidenii* by *Mycosphaerella nubilosa*

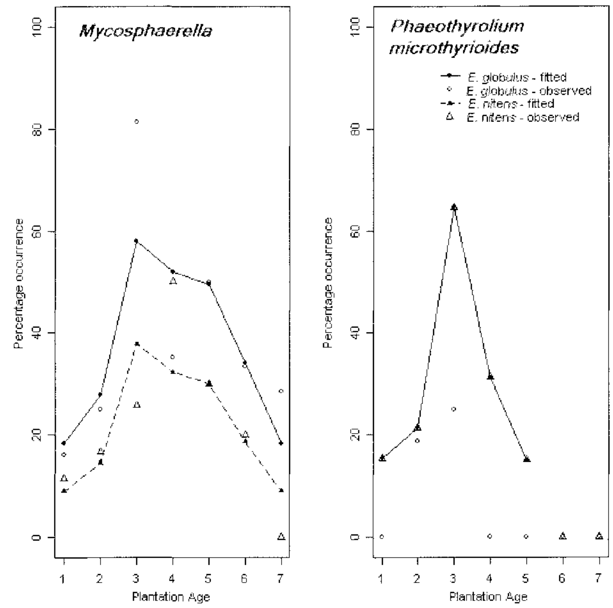


FIG. 4 — Percentage of plantations of Eucalyptus globulus *and* E. nitens *with symptoms of damage caused by leaf diseases in age classes from 1–7 years (p>0.05).*

(Cooke) Hansf. to be highest at age 2–4 years in several trials in New South Wales.

The second most commonly recorded fungal leaf disease was *Phaeothyrolium microthyrioides.* This species was widespread on juvenile foliage and is recognised by the characteristic "oil blotches" on leaves (pl. 3B). It is much more commonly found on *E. nitens* where its presence changed significantly over time (p <0.001). Presence appeared to peak in three-year-old plantations. The presence of *P. microthyrioides* on eucalypt and *Corymbia* plantations in New South Wales was recorded by Carnegie (2007a, b) although not on either *E. globulus* or *E. nitens.*

Other fungal leaf diseases were *Kirramyces eucalypti* (Cooke & Massee) J. Walker, B. Sutton & Pascoe, *Pseudocercospora eucalyptorum* Crous, M. J. Wingf. & Marasas and *Sonderhenia eucalypticola* (A. R. Davis) H. J. Swart & J. Walker (pl. 3C, D, E).

Root diseases

Only one root disease, *Armillaria* sp. (pl. 4), was encountered.

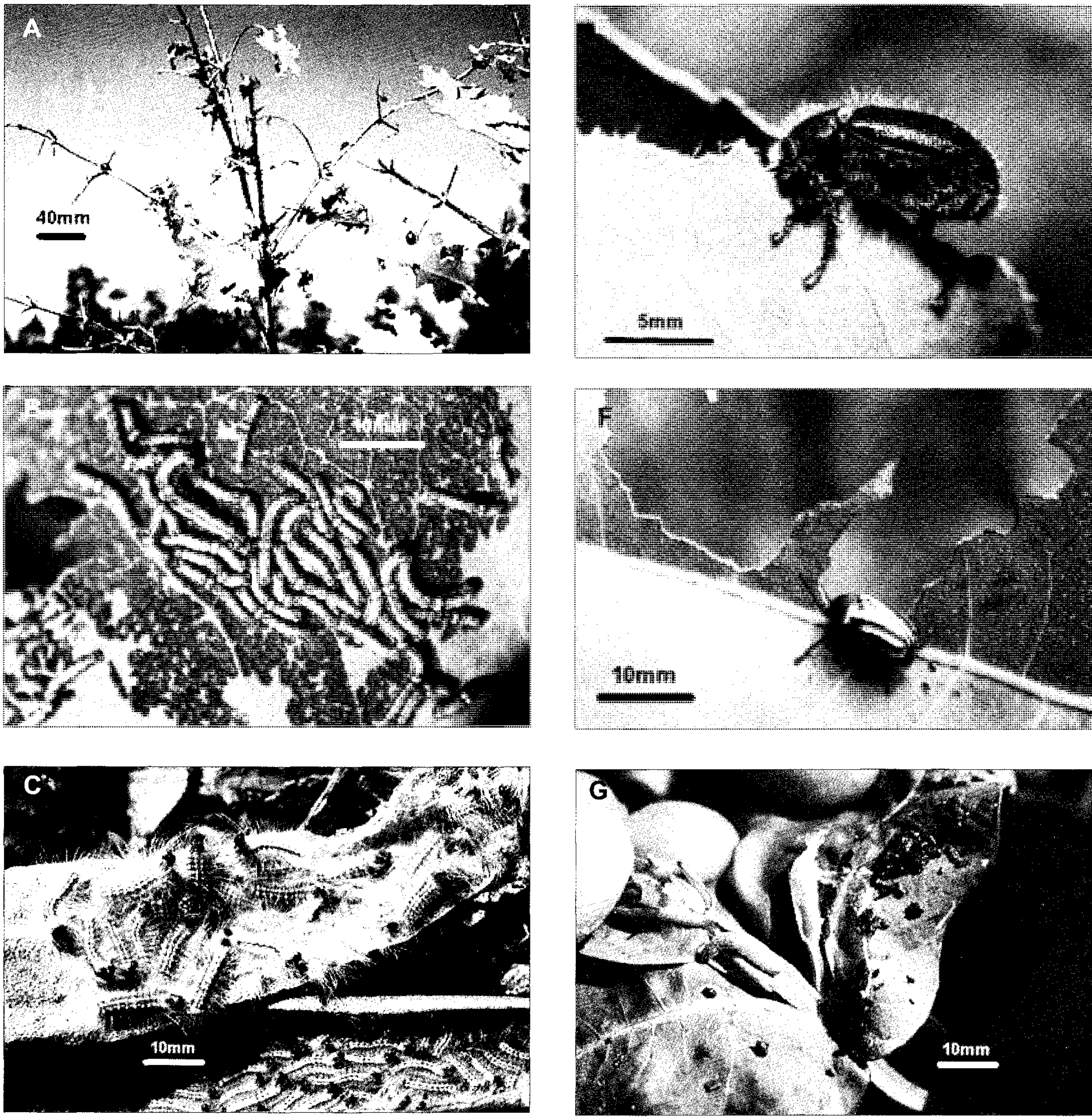
Other fungal pathogens

Neither shoot diseases nor stem canker diseases were common or widespread.

DISCUSSION

Many previous studies of individual insect pest and fungal pathogen taxa on Tasmanian eucalypt plantations have been reported in the literature (Bashford 1993, Yuan 1999). This paper represents the first attempt to quantify temporal distribution of these pests and pathogens together in young *E. globulus* and *E. nitens* plantations.

The two host eucalypt species are regarded as being closely related taxonomically, both being placed in the series *Globulares* Blakely (Brooker 2000), but while *E. globulus* has its main centre of natural distribution in Tasmania,



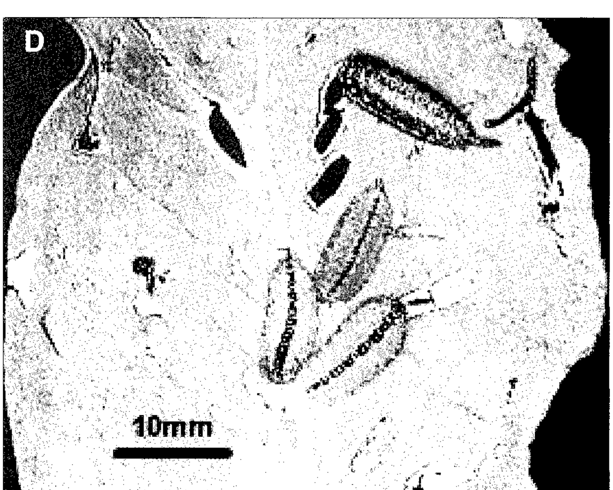


PLATE 1

(A) Defoliation damage on juvenile Eucalyptus nitens *caused by Chrysomelinae* (Paropsisterna agricola) *adult beetles. (B)* Mnesampela privata *larvae feeding on* E. nitens *juvenile leaf. (C) Larvae of* Uraba lugens *on adult foliage of* E. globulus. *(D)* Gonipterus scutellatus *larvae feeding on* E. globulus juvenile *leaf. (E)* Heteronyx *sp. adult feeding on* E. nitens *juvenile leaf. (F)* Cadmus australis *beetle and damage on* E. nitens leaf. *(G) Larva of Tortricidae in young juvenile shoot of* E. nitens.

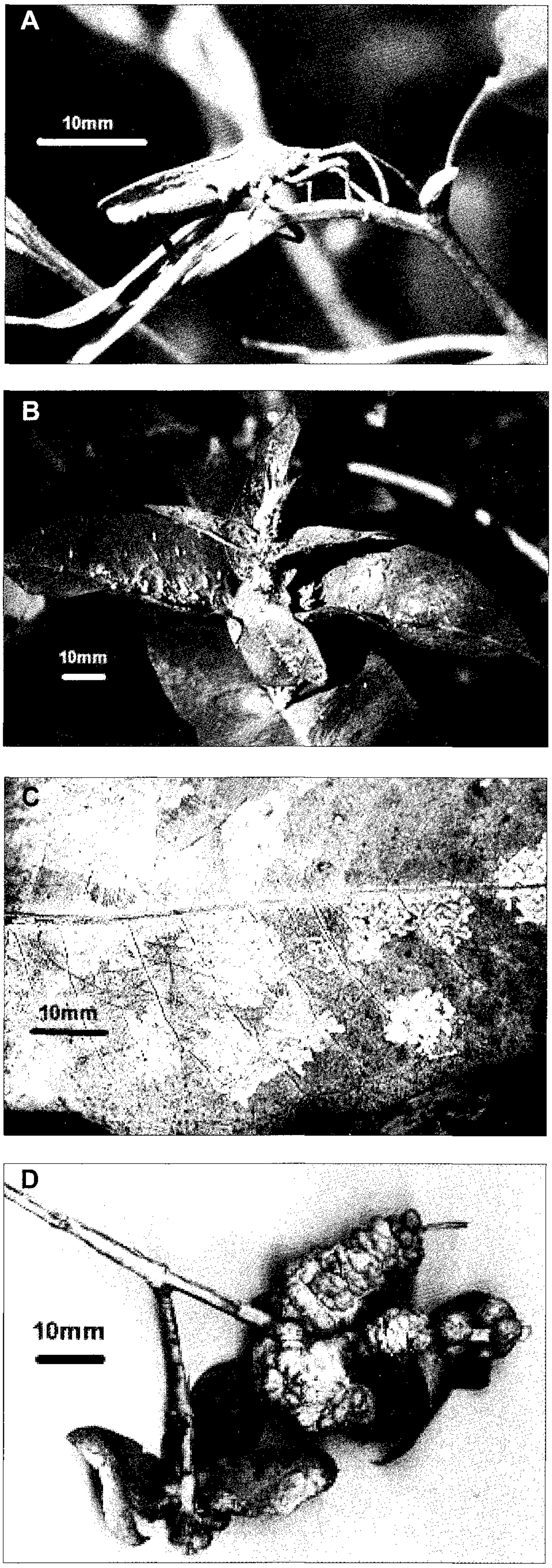


PLATE 2

*(A) Coreid bug (*Amorbus obscuricornis*) on eucalypt shoot (B)* Ctenarytaina eucalypti *on juvenile foliage of* Eucalyptus *globulus. (C)* Acrocercops laciniella *mines on* E. nitens *leaf. (D) Galls on* E. globulus *shoot caused by* Ophelimus *sp.*

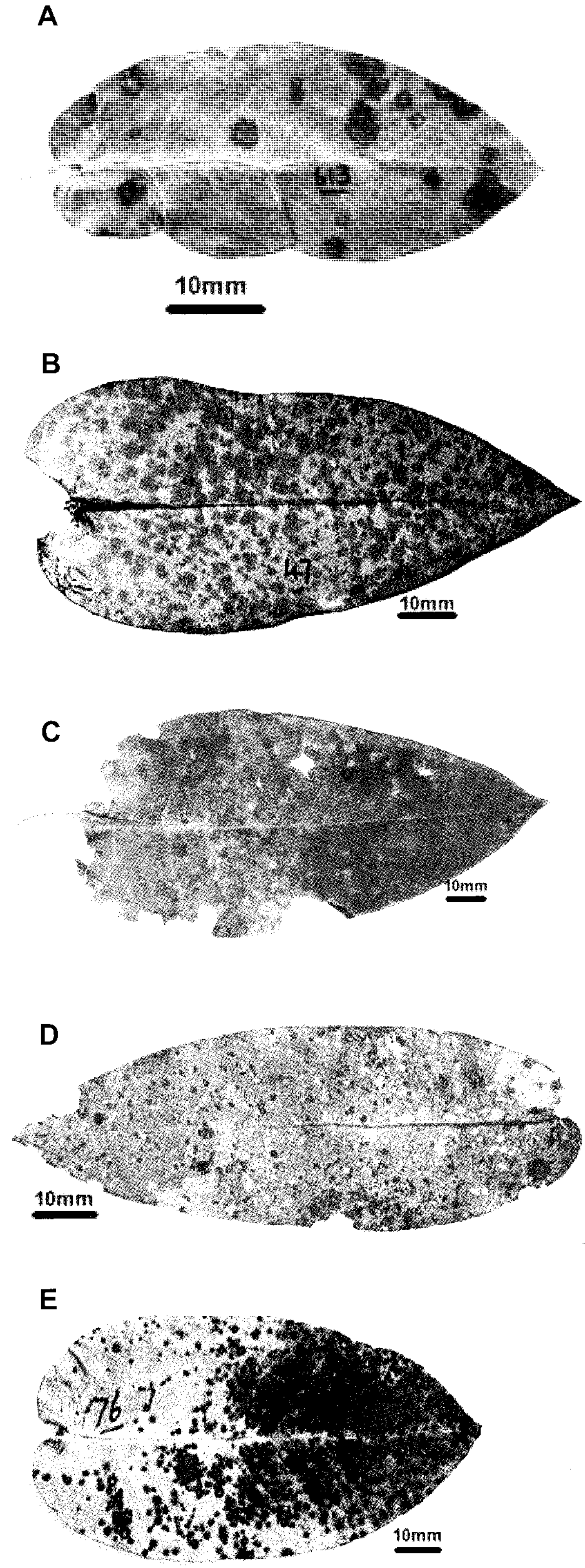


PLATE 3

(A) Mycosphaerella *sp. "Crinkle leaf" lesions on juvenile* Eucalyptus nitens *leaf. (B) Lesions of* Phaeothyrolium microthyrioides *on juvenile* E. nitens *leaf. (C) Lesions of* Kirramyces eucalypti *on juvenile* E. nitens *leaf. (D) Lesions of* Pseudocercospora eucalyptorum *on juvenile* E. nitens. *(E) Lesions of* Sonderhenia eucalypticola *on juvenile foliage of* E. globulus.

PLATE 4
Armillaria *sp. fungal weft at base of dead eucalypt plantation tree.*

E. nitens is an introduced species, occurring naturally in Victoria and New South Wales. At the commencement of this study in 1998, both species had a plantation history of approximately 20 years in Tasmania. Both species exhibit strong heterophylly with the transition to adult foliage exhibiting a similar yet significantly different pattern (fig. 2). The exotic species, *E. nitens*, was shown to be approximately equivalently susceptible to pest and pathogen attack as its native relative, *E. globulus*. (table 2, figs 3, 4).

A total of 45 pest/pathogen taxa were identified in this study with approximately 78% of the taxa occurring on each host. The most commonly encountered pest/pathogen taxa were Chrysomelinae, *Mycosphaerella* spp., *M. privata*, *A. laciniella*, *P. microthyrioides*, *U. lugens* and *G. scutellatus* (table 2). Some of the more common pests/pathogens, while being encountered on both hosts, clearly preferred one host, e.g., *P. microthyrioides*, *E. nitens*, *G. scutellatus*, *E. globulus*.

Attack trends of foliar pests and pathogens with age in plantations up to seven years of age reflected preference for either juvenile or adult foliage. Preference for juvenile foliage was exemplified by *M. privata* (fig. 3). With the fungal leaf pathogens *Mycosphaerella* spp. and *P. microthyrioides*, there was a build up to a peak at age three to four years as plantation canopies closed creating the moister microclimatic conditions that favour some leaf pathogens. Occurrence then declined as the proportion of more resistant adult foliage increased in the plantations (fig. 4). *U. lugens* and *G. scutellatus* are examples of pests that build up slowly as the amount of adult foliage increases (fig. 3).

Information provided in this paper will enable managers of Tasmanian eucalypt plantations to improve timing and efficacy of specific insect pest and fungal pathogen monitoring and management programs. For example, monitoring for Chrysomelinae, *G. scutellatus* and *U. lugens* need only occur in plantations aged three years or greater, whereas monitoring for *M. privata* need only occur in plantations up to five years old. For *Mycosphaerella* spp., monitoring need only occur in plantations aged between two and six years.

ACKNOWLEDGEMENTS

Gunns Limited (formerly North Forest Products) is acknowledged for its support of this work and for the preparation of figure 1. The authors are grateful to Dr Yuan Zi Qing (formerly of Cooperative Research Centre for Sustainable Production Forestry) for his identification of many of the leaf pathogenic fungi, Dr John La Salle (Australian National Insect Collection) for his identification of *Ophelimus* sp., and Mr Dick Bashford (Forestry Tasmania) for his identification of *Cardiaspina* spp. and *Hyalinaspis subfasciata*. Drs Christine Stone, Geoff Allen and Humphrey Elliott kindly commented on the manuscript.

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(accepted 26 February 2008)