PAN-PACIFIC ENTOMOLOGIST
77(4): 249–253, (2001)

RESISTANCE OF *EUCALYPTUS* SPECIES TO *GLYCASPIS BRIMBLECOMBEI* (HOMOPTERA: PSYLLIDAE) IN THE SAN FRANCISCO BAY AREA

ERIC B. BRENNAN[1,2], G. FREDERIC HRUSA[3], STEVEN A. WEINBAUM[1], & WALTER LEVISON JR.[4]

[1]Department of Pomology, University of California, Davis, California 95616
[3]California Department of Food and Agriculture, Sacramento, California 95832-1448
[4]Walter Levison, Consulting Arborist, Millbrae, California 94030

Abstract.—The resistance of 21 cultivated *Eucalyptus* species to *Glycaspis brimblecombei* Moore was assessed from 1998 to 2000 in the San Francisco Bay area of Northern California. Based on the presence of eggs and nymphs, and the occurrence and severity of tree defoliation, the majority of the species were rated as resistant or tolerant including *E. cinerea* F. Muell., *E. cladocalyx* F. Muell., *E. ficifolia* F. Muell., *E. globulus* Labill., *E. grandis* Hill ex Maiden, *E. paniculata* Smith, *E. platypus* Hook, *E. polyanthemos* Schauer, *E. pulverulenta* Sims, *E. robusta* Smith, *E. saligna* Smith, *E. sideroxylon* A. Cunn ex Woollis, and *E. viminalis* Labill. Four species (*E. diversicolor* F. Muell., *E. leucoxylon* F. Meull., *E. macrandra* F. Muell, ex Benth and *E. nicholii* Maiden & Blakely) were rated as tolerant to moderately susceptible. Only three species (*E. camaldulensis* Dehnh., *E. rudis* Endl. and *E. tereticornis* Smith) exhibited heavy defoliation and were rated as moderately to highly susceptible. Leaf epicuticular wax appears to be involved with resistance because all glaucous species or glaucous leaf types within a species were resistant.

Key Words.—Insecta, red gum lerp psyllid, resistance, *Eucalyptus*, *Glycaspis brimblecombei*, glaucousness.

The red gum lerp psyllid, *Glycaspis brimblecombei* Moore (Moore 1964), was first reported in California in 1998 and became the sixth *Eucalyptus* psyllid species found in the state (Brennan et al. 1999). Prior to the arrival of *G. brimblecombei*, the blue gum psyllid (*Ctenarytaina eucalypti* Maskell) was the only economically important *Eucalyptus* psyllid in California. Whereas *C. eucalypti* affected primarily plantations of the cut foliage species *E. pulverulenta* Sims (Dahlsten et al. 1998), *G. brimblecombei* has attacked several *Eucalyptus* species in a variety of settings (street and freeway plantings, parks, commercial landscapes, schools, private gardens, and commercial fiber plantings).

Little is known about the resistance of *Eucalyptus* species to *G. brimblecombei*. In its native range (Australia), *G. brimblecombei* occurs on eight *Eucalyptus* species (*E. blakelyi* Maiden, *E. brassina* Blake, *E. bridgesiana* Baker, *E. camaldulensis* Dehnh., *E. camphora* Baker, *E. dealbata* Cunn. ex Schauer, *E. mannifera* ssp *maculosa* Baker, *E. nitens* Deane & Maiden, and *E. tereticornis* Smith (Moore 1970, 1983, 1988; Morgan 1984; Carver 1987); however, with exception of recent studies (Brennan & Weinbaum in press-a, in press-b, in press-c) on resistance mechanisms of *E. globulus*, we are unaware of any work on the resistance of other *Eucalyptus* to this psyllid species. This paper reports on the resistance of 21 *Eucalyptus* species to *G. brimblecombei* in the San Francisco bay region of Northern California.

[2] Current address: United States Department of Agriculture, Agricultural Research Station, 1636 East Alisal Street, Salinas, California 93905

Materials and Methods

To assess the resistance of *Eucalyptus* species to *G. brimblecombei*, we conducted a survey during Jul and Aug, 1999, and Oct and Nov, 2000. The survey was based on our preliminary observations during Jul and Aug, 1998 (when the psyllid was first found in northern California). The survey took place in the cities of Albany, East Palo Alto, El Cerrito, Fremont, Oakland, Palo Alto, and San Francisco. We assessed the resistance to *G. brimblecombei* by recording the presence of eggs, and early and late stage nymphs of *G. brimblecombei* on expanding and expanded leaves of shoots in the lower 3m of the canopy, and noted defoliation in the entire canopy. Defoliation was assessed qualitatively by noting the sky visible through the canopy and retention of recently expanded leaves. To minimize potential individual tree variation, in most cases we rated defoliation on a group of individuals within each species. Each year approximately three terminal shoots each from at least three to five branches distributed around the tree canopy were inspected from each individual. Each year, three or more individuals of each species were observed once except for *E. diversicolor, E. robusta* and *E. saligna* where only one individual was observed. In most cases the same trees were observed during both years of the survey. The trees included in the survey were estimated to be at least 10 to 15 years old. Where juvenile and adult form leaves were present, we assessed resistance on both leaf types.

Specimens of each species were collected, pressed and determined in the laboratory. Consulted herbaria included: CDA (California Department of Food and Agriculture), University of California & Jepson Herbaria, California Academy of Sciences, University of California, Davis. Plant vouchers were retained at CDA where they are available for review.

The following rating system was used to assess psyllid resistance.

1. No eggs or nymphs present.
2. Only eggs present.
3. Eggs and early instar nymphs present.
4. Eggs, early and late instar nymphs present but no defoliation of host plant.
5. Eggs, early and late instar nymphs present, and light defoliation of host plant.
6. Eggs, early and late instar nymphs present, and heavy defoliation of host plant.

Based on this rating system, we classified the species as resistant (rating 1–3), tolerant (4), moderately susceptible (5), and highly susceptible (6).

Results

The results of the survey were consistent across both years of the survey and thus only the overall resistance rating is reported (Table 1). There was considerable variation in the resistance to *G. brimblecombei* among the *Eucalyptus* species, but little variation between individual trees within a species at each site. Although eggs and nymphs were found on the leaves of most species, only three (*E. camaldulensis, E. rudis* and *E. tereticornis*) exhibited heavy defoliation. By November 2000, the highly susceptible species were nearly completely defoliated and many appeared close to death. All of the glaucous-leaved species (*E. cinerea, E. polyanthemos, E. pulverulenta*) were resistant. Similarly the glaucous juvenile leaves of *E. globulus* were resistant relative to the glossy adult leaves. *G. brimblecombei* eggs and early stage nymphs were generally only found on tolerant

Table 1. Relative resistance of 21 *Eucalyptus* species to *Glycaspis brimblecombei*.

Species[A]	Location[B]	Resistance: 1–6 Rating[C]	Resistance: Descriptive Rating[D]
E. camaldulensis Dehnh.	AW, SU	6	Highly Susceptible
E. cinerea F. Muell. ex Benth.	AW, SU	1	Resistant
E. cladocalyx F. Muell	AW	1–3	Resistant
E. diversicolor F. Muell.	SU	3–5	Tolerant–Mod. Susceptible
E. ficifolia F. Muell.	OK, SF	1	Resistant
E. globulus Labill. (juvenile leaves)	AW, SU, EC	1	Resistant
E. globulus Labill. (adult leaves)	AW, SU, EC	1–4	Resistant–Tolerant
E. grandis Hill ex Maiden	AW	4	Tolerant
E. leucoxylon F. Muell.	SU	5	Tolerant–Mod. Susceptible
E. macrandra F. Muell. ex Benth	AW, SU	4–5	Tolerant–Mod. Susceptible
E. nicholii Maiden & Blakely	OK, AB	4–5	Tolerant–Mod. Susceptible
E. paniculata Smith	AW	1–2	Resistant
E. platypus Hook. (including forms approaching *E. nutans* F. Muell.)	SU	1–3	Resistant–Tolerant
E. polyanthemos Schauer	AW, SU	1	Resistant
E. pulverulenta Sims	SU	1	Resistant
E. robusta Smith	OK	1–3	Resistant
E. rudis Endl.	EC, OK, PA	5–6	Mod.–Highly Susceptible
E. saligna Smith	SU	1	Resistant
E. sideroxylon A. Cunn. ex Woollis	SU	1–4	Resistant–Tolerant
E. spathulata Hook ssp. *spathulata*	OK	1	Resistant
E. tereticornis Smith	AW	6	Highly Susceptible
E. viminalis Labill. ssp. *viminalis*	AW, SU, EP	1–4	Resistant–Tolerant

[A] *Eucalyptus* nomenclature follows that in Flora of Australia (1988). Unless otherwise noted, resistance ratings apply to shoots with the adult form leaves. Resistance was rated for all species in 1999 and 2000, with exception of and *E. paniculata*, *E. saligna* and *E. viminalis* where resistance was only rated in 1999. Three or more individuals were observed for all species except *E. diversicolor*, *E. robusta* and *E. saligna* where only one individual of each was observed.

[B] AB = Albany, AW = Ardenwood Historic Park (Fremont), EC = El Cerrito, EP = East Palo Alto, OK = Oakland, PA = Palo Alto, SF = San Francisco, SU = Stanford University (Palo Alto).

[C] Resistance Scale 1–6: 1 = No eggs or nymphs. 2 = Eggs only. 3 = Eggs and early instar nymphs. 4 = Eggs, early and late instar nymphs, but no defoliation. 5 = Eggs, early and late instar nymphs, and light defoliation. 6 = Eggs, early and late instar nymphs and heavy defoliation.

[D] Mod. = Moderately.

species such as *E. globulus* or *E. sideroxylon* when these species were growing in proximity to highly susceptible species.

Discussion

The results indicate clear differences in the resistance of *Eucalyptus* species to *G. brimblecombei*. Although eggs were found on most of the species, early and late stage nymphs occurred on less than half of the species, and only three (*E. camaldulensis*, *E. rudis* and *E. tereticornis*) were heavily defoliated.

Resistance of *Eucalyptus* species to *G. brimblecombei* may be influenced by abiotic factors (i.e., ambient temperature, soil conditions, exposure) because we observed more defoliation of moderately to highly susceptible species such as *E. rudis* in warmer areas such as Palo Alto than in cooler areas such as El Cerrito or San Francisco. Resistance may also be affected by tree vigor whereby younger more vigorous trees of susceptible species may appear resistant or tolerant in the first few years of growth. In addition, as is the case with *E. globulus*, resistance of other species may differ on the juvenile versus adult form leaves. Despite these possible influences on resistance, we suggest caution in future plantings of the moderately and highly susceptible species prior to the identification of resistant varieties or the establishment of successful biological controls. Studies with species of *Leucaena* and *Pyrus* have found considerable within and between species variation to other economically important psyllids (i.e., *Heteropsylla cubana* Crawford, *Psylla pyricola* Foerster, *Cacopsylla pyri* L.) (Sorensson & Brewbaker 1987, Bell & Stuart 1990, Berrada et al. 1995). Future studies should access within species resistance to *G. brimblecombei* of commonly planted and economically important species such as *E. camaldulensis*.

It is unclear if defoliation on the highly susceptible species was caused by direct feeding damage of the psyllid or by sooty mold that thrived on the psyllid honeydrew. In other non-myrtaceous genera, sooty mold growth on homopteran honeydew can increase leaf temperatures by several degrees (Wood et al. 1988), reduce light penetration to the leaf surface by up to 98% and thus reduce net photosynthesis by as much as 70% (Wood et al. 1988, Kaakeh et al. 1992), and cause premature leaf abscission (Sparks & Yates 1991). *Eucalyptus* species that experienced the most defoliation typically exhibited the greatest amount of sooty mold on their leaves. Sooty mold susceptibility is related to leaf surface morphology (Sparks & Yates 1991), which may help to explain differences in defoliation between the moderately susceptible (*E. leucoxylon*, *E. macrandra*) and highly susceptible species (*E. camaldulensis*, *E. rudis* and *E. tereticornis*).

Apparently glaucousness in *Eucalyptus* is involved in resistance to *G. brimblecombei*. Glaucousness is common in *Eucalyptus* and is due to epicuticular wax that occurs as tubes ('structural waxes') and plates ('non-structural waxes') (Barber 1955, Hallam & Chambers 1970). Tube waxes give leaves a 'bloom' (i.e., *E. cinerea*, *E. pulverulenta* and juvenile form leaves of *E. globulus*) and can be easily removed by rubbing the leaf. In contrast plate waxes are difficult to remove by rubbing and give leaves a dull matt appearance (e.g., *E. polyanthemos*). The epicuticular wax on the glaucous juvenile leaves of *E. globulus* had a negative effect on the survival and stylet probing behavior of *G. brimblecombei* adults (Brennan & Weinbaum 2001, in press-a). The epicuticular wax increased the slipperiness of glaucous juvenile leaves and prevented the psyllid from adhering to the leaf surface (Brennan & Weinbaum in press-b). This resistance mechanism may explain the absence of *G. brimblecombei* eggs on the glaucous juvenile leaves of *E. globulus*, and both the glaucous juvenile and adult leaves of *E. pulverulenta* and *E. cinerea*. It is likely that some other mechanism confers resistance to species such as *E. polyanthemos* where the glaucousness is due to plate waxes, and other nonglaucous yet resistant species (i.e., *E. cladocalyx*, *E. ficifolia*, *E. nicholii*, *E. platypus*, *E. spathulata*).

Cultivated *Eucalyptus* provide some of the most challenging identification problems in plants. The taxa listed in this paper were carefully compared to annotated herbarium specimens and the determinations are felt to be as reliable as is possible considering that wild and cultivated material of the same species are often considerably dissimilar in appearance. Several resistant or tolerant specimens, that may represent hybrids or their derivatives, remain unnamed.

ACKNOWLEDGMENT

We thank Ira M. Blitz and Nancy Brownfield of the East Bay Regional Park District, and Carol Sweetapple of Stanford University Facilities Operations, and Ronnie Eaton of the Alameda County Department of Agriculture for their cooperation.

LITERATURE CITED

Barber, H. N. 1955. Adaptive gene substitutions in Tasmania eucalypts: I. Genes controlling the development of glaucousness. Evolution, 9: 1–14.

Bell, R. L. & L. C. Stuart. 1990. Resistance in Eastern European *Pyrus* germplasm to pear psylla nymphal feeding. HortScience, 25: 789–791.

Berrada, S., T. X. Nguyen, J. Lemoine, J. Vanpoucke & D. Fournier. 1995. Thirteen pear species and cultivars evaluated for resistance to *Cacopsylla pyri* (Homoptera: Psyllidae). Environmental Entomology, 24: 1604–1607.

Brennan, E. B., R. J. Gill, G. F. Hrusa & S. A. Weinbaum. 1999. First record of *Glycaspis brimblecombei* (Moore) (Homoptera: Psyllidae) in North America: Initial observations and predator associations of a potentially serious new pest of *Eucalyptus* in California. Pan-Pacific Entomologist, 75: 55–57.

Brennan, E. B. & S. A. Weinbaum. (2001). Performance of adult psyllids in no-choice experiments on juvenile and adult leaves of *Eucalyptus globulus*. Entomologia Experimentalis et Applicata, 100: 179–185.

Brennan, E. B. & S. A. Weinbaum. (in press-a). Stylet penetration and survival of 3 psyllid species on adult leaves and 'waxy' and 'de-waxed' juvenile leaves of *Eucalyptus globulus*. Entomologia Experimentalis et Applicata.

Brennan, E. B. & S. A. Weinbaum. (in press-b). The effect of epicuticular wax on adhesion of psyllids to glaucous juvenile and glossy adult leaves of *Eucalyptus globulus* Labill. Australian Journal of Entomology.

Carver, M. 1987. Distinctive motory behavior in some adult psyllids (Homoptera: Psyllidae). Journal of the Australian Entomological Society, 26: 369–372.

Dahlsten, D. L., D. L. Rowney, W. A. Copper, R. L. Tassen, W. E. Chaney, K. L. Robb, S. Tjosvold, M. Bianchi & P. Lane. 1998. Parisitoid wasp controls blue gum psyllid. California Agriculture, 52: 31–34.

Hallam, N. D. & T. C. Chambers. 1970. The leaf waxes of the genus *Eucalyptus* L'Hérit. Australian Journal of Botany, 18: 335–389.

Kaakeh, W., D. G. Pfeiffer & R. P. Marini. 1992. Combined effect of spirea aphid (Homoptera: Aphididae) and nitrogen fertilization on net photosynthesis, total chlorophyll content, and greeness of apple leaves. Journal of Economic Entomology, 85: 939–946.

Moore, K. M. 1964. Observations on some Australian forest insects. 18. Four new species of *Glycaspis* (Homoptera: Psyllidae) from Queensland. Proceedings of the Linnean Society of New South Wales, 89: 163–166.

Moore, K. M. 1970. Observations on some Australian forest insects. 23. A revision of the genus *Glycaspis* (Homoptera: Psyllidae) with descriptions of seventy-three new species. Australian Zoologist, 15: 248–342.

Moore, K. M. 1983. New species and records of *Glycaspis* Taylor (Homoptera: Spondyllaspidae) with phyletic groupings. Journal of the Australian Entomological Society, 22: 177–184.

Moore, K. M. 1988. Associations of some *Glycaspis* species (Homoptera: Spondyliaspididae) with their *Eucalyptus* species hosts. Proceedings of the Linnean Society of New South Wales, 110: 19–26.

Morgan, F. D. 1984. Psylloidea of South Australia, D. J. Woolman, Government Printer, South Australia.

Sorensson, C. T. & J. L. Brewbaker. 1987. Psyllid resistance of Leucaena species and hybrids. Leucaena Research Reports, 7: 29–31.

Sparks, D. & I. E. Yates. 1991. Pecan cultivar susceptibility to sooty mold related to leaf surface morphology. Journal of the American Society of Horticultural Science, 116: 6–9.

Wood, B. W., W. L. Tedders & C. C. Reilly. 1988. Sooty mold fungus on pecan foliage suppresses light penetration and net photosynthesis. HortScience, 23: 851–853.

Received 8 Dec 2000; Accepted 20 Aug 2001