Comparison of Four Trap Types for Ambrosia Beetles (Coleoptera, Scolytidae) in Brazilian *Eucalyptus* Stands

C.A.H. FLECHTMANN,[1] A.L.T. OTTATI,[2] AND C. W. BERISFORD[3]

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ABSTRACT *Eucalyptus* spp. plantations represent >60% of the reforested area in Brazil. Although ambrosia beetle attacks on live trees were at first nonexistent, they have begun to appear with greater frequency. Monitoring for pest insects is a key factor in integrated pest management, and baited traps are one of the most widely used methods for insect population detection and survey. We compared the efficiency of the most widely used trap in Brazil to survey for ambrosia beetles and other Scolytidae, the ESALQ-84 type, with other traditionally employed traps: the multiple funnel (Lindgren trap); drainpipe; and slot (Theyson) traps, in a *Eucalyptus grandis* Hill ex Maiden stand in Brazil. The ESALQ-84 trap was the most efficient in trapping *Hypothenemus eruditus* Westwood and *Hypothenemus obscurus* (F.); the multiple funnel trap caught significantly more *Cryptocarenus diadematus* Eggers; whereas the slot trap caught more *Premnobius cavipennis* Eichhoff and *Xyleborus affinis* Eichhoff than the other traps. The drainpipe trap was the least effective trap overall. When corrected for number of beetles caught per trap surface area, catches were significantly higher on the ESALQ-84 trap for the majority of the species analyzed, probably because of a smaller trap surface area. The slot trap was recommended for it caught overall more beetles of the three most economically important scolytid species in eucalypt plantations in Brazil, *P. cavipennis*, *X. affinis*, and *X. ferrugineus*.

KEY WORDS trap efficiency, trap design, trap surface area, Brazil, vertical profile

BRAZILIAN MANAGED PLANTATIONS are unusual in that >95% are composed of exotic tree species, mainly *Eucalyptus* and *Pinus*. *Eucalyptus* alone is responsible for >60% of the plantations (ANFPC 1996). Since the beginning of commercial planting in the mid-1960s, several native insects have adapted to the exotic trees, mainly defoliating Lepidoptera and leaf-cutting ants, causing extensive and frequent damage (Iede 1985).

Native scolytids, particularly ambrosia beetles, have attacked eucalyptus trees since their introduction in the beginning of the century, but significant economic losses have not been reported (Iglesias 1914, Pinheiro 1962). This situation appears to be changing with numerous reports of successful attacks by ambrosia beetles on stumps and apparently healthy *Eucalyptus grandis* Hill ex Maiden (Rocha 1993, Farias 1996).

In most insect pest management programs, a suitable monitoring system is vital for estimating the targeted population in the field or determining population trends; also, it could help determine if any control measures are warranted (Milligan et al. 1988). Traps baited with attractants are one of the most widely used and practical methods for detection and survey of insect populations, scolytids included (Chénier and Philogène 1989, Turchin and Odendaal 1996). Moreover, traps can be a significant component in scolytid pest control (Bakke et al. 1983, Abgrall 1986, Egger 1987, Lindgren and Fraser 1994).

Scolytids have low visual acuity (Byers et al. 1989, Byers 1995), based on their low number of ommatidia (Chu et al. 1975, Byers et al. 1989). Yet in many species, visual orientation may play a role in host location and selection (Schönherr 1977, Mathieu et al. 1997), and an interaction between host attractants and visual stimuli might occur (Vité and Bakke 1979, Borden et al. 1982). Therefore, of the several factors that can influence the efficacy of a trap, its shape and design might play an important role (McLean and Borden 1979, Lindgren et al. 1983, Borden et al. 1986).

For a number of scolytids, especially the bark beetles, vertically oriented traps or traps that mimic tree trunks elicit stronger responses than horizontally oriented or non-tree-shaped traps (Entwistle 1963, Billings et al. 1976, Vité and Bakke 1979, Byers 1995). *Ips typographus* L. trapping is affected by trap design; it is more efficiently caught in flight intercept and funnel traps than in landing and window traps (Niemeyer and Watzek 1982, Egger 1987).

In Brazil, survey and detection of Scolytidae is normally conducted with a "pane type" trap (Flechtmann et al. 1995). None of the traps traditionally used in North America and Europe had been tested in Brazil before the research reported here.

[1] Department of Biology, FEIS/UNESP, Av. Brasil, 56, 15385-000 - Ilha Solteira, SP, Brazil.
[2] Department of Plant Production, FCA/UNESP, Fazenda Experimental Lageado, P.O. Box 237, 18603-970, Botucatu, SP, Brazil.
[3] Department of Entomology, University of Georgia, 413 Biological Sciences Building, Athens, GA 30605-2655.

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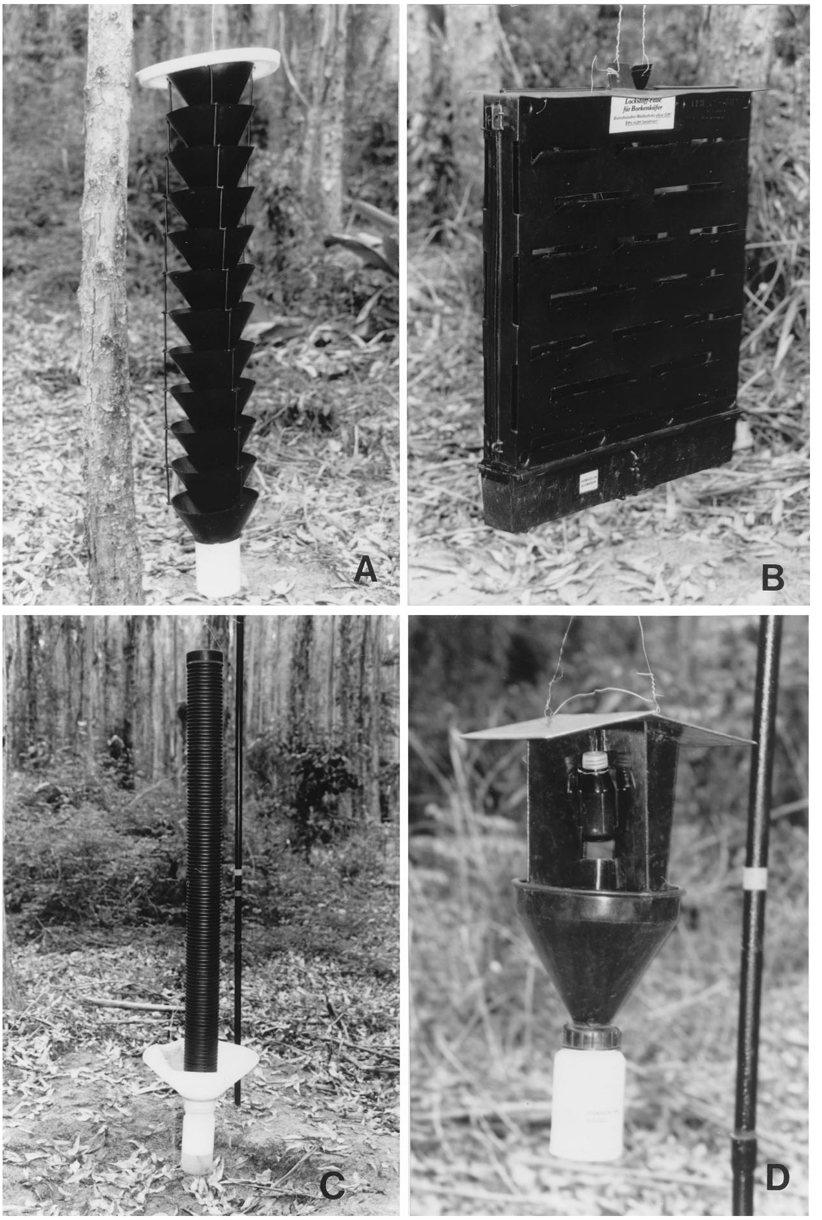

Fig. 1. Trap types. (A) Multiple funnel trap. (B) Slot trap. (C) Drainpipe trap. (D) ESALQ-84 trap.

The objective of this experiment was to compare the efficacy of the most widely used trap type in Brazil, the ESALQ-84 (Berti and Flechtmann 1986), with the traps most commonly employed in North America and Europe: the Canadian multiple funnel trap (Lindgren 1983), the German slot trap (Niemeyer et al. 1983) and the Scandinavian drainpipe trap (Bakke et al. 1983).

Materials and Methods

Site. The traps were deployed in an *E. grandis* Hill ex Maiden (provenance: Australia) stand owned by Aracruz Celulose S.A. This stand was located in Nova Viçosa, Bahia state, Brazil, at the geographic coordinates of 17° 55′ latitude S and 39° 47′ longitude W, and an altitude of 75 m above sea level. The stand characteristics were as follows: 19 ha, planted in December 1989, mean diameter at breast height (dbh) of 18.9 cm, mean basal area 28.8 m^2/ha, tree height of 27.0 m, density of 1,028 trees per hectare, yellow podzolic soil type with sandy/loamy texture and flat topography. The vegetation surrounding the stand was composed exclusively of other *E. grandis* stands.

Traps and Deployment. We used four different trap types, the German slot trap (Theysohn, Salzgitter, Germany), the Brazilian ESALQ-84 trap (Polplast, Piracicaba, SP, Brazil), the Canadian multiple funnel trap (Lindgren, Phero Tech, Delta, BC, Canada), and the Scandinavian drainpipe trap (A/S Borregaard, Sarpsborg, Norway). All of the traps were black (Fig. 1).

The four trap types differed in surface area; the multiple funnel, slot, drainpipe, and Brazilian traps had surface areas of 5,796.2 cm^2 (90 by 20.5 cm), 4,183.0 cm^2 (44.5 by 47.0 cm), 5,274.7 cm^2 (146.0 by 11.5 cm) and 876.6 cm^2 (15.6 by 14.0 cm), respectively.

The traps were deployed in six lines, each containing one trap of each type. The traps were 5 m apart within each line, and lines were spaced 20 m apart. All traps were baited with 95% ethanol, contained in a 32-ml dispenser with a 5-mm hole drilled in the cap, providing a release rate of ≈0.52 g/d at 21°C (determined gravimetrically). The dispensers were placed in the middle of the traps, and the dispensers of all traps were at 1 m above the ground. Beetles trapped were collected every 7 d, at which time traps were randomized within each line (Phillips et al. 1988) to reduce positional effects (Volz 1988). Collections began on 18 June 1997, and ended on 10 June 1998, resulting in 52 collecting dates (one full year).

In the tropics there is no clear distinction among the spring, summer, fall, and winter seasons; usually it is more correct to state that there are two seasons, hot and rainy and cold and dry. We considered the months of October through March to correspond to the hot/rainy season, and the months of June through September to the cool/dry season.

Experimental Design and Data Analysis. The experimental design was a randomized complete block. To remove heteroscedasticy, beetle catch data were transformed into $\sqrt{(x + 0.5)}$ (Phillips 1990). Beetle catches among the different trap types were compared by PROC GLM and treatment means were separated by Tukey test (SAS Institute 1990).

Results

A total of 21,554 scolytid specimens was trapped, representing 38 species. The 10 most abundant species (comprising >97% of total specimens) were used in the analyses, including *Cryptocarenus heveae* (Hagedorn), *Cryptocarenus seriatus* Eggers, *Cryptocarenus diadematus* Eggers, *Hypothenemus bolivianus* (Eggers), *Hypothenemus eruditus* Westwood, and *Hypothenemus obscurus* (F.) in the Cryphalini, and *Ambrosiodmus hagedorni* (Iglesias), *Premnobius cavipennis* Eichhoff, *Xyleborus affinis* Eichhoff, and *Xyleborus ferrugineus* (F.) in the Xyleborini.

The ESALQ-84 trap caught significantly more *H. eruditus* and *H. obscurus.* However, *C. diadematus* was trapped in higher numbers in the multiple funnel trap, whereas *X. affinis* and *P. cavipennis* were trapped significantly more in the slot trap. *X. ferrugineus*, *C. heveae,* and *H. bolivianus* were caught equally well in the slot and multiple funnel, ESALQ-84 and multiple funnel, and slot and ESALQ-84 traps, respectively. *A. hagedorni, C. seriatus,* and "other Scolytidae" (sum of all other species but the 10 used in the analyses) were least trapped in the drainpipe trap. No species showed a preference for the drainpipe over the other trap types ($P < 0.05$, Figs. 2 and 3).

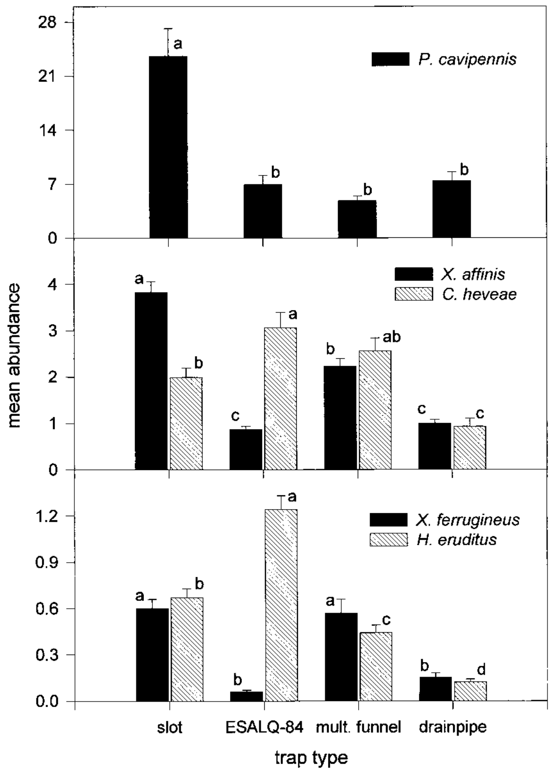

Fig. 2. Mean ± SE numbers per trap of Scolytidae caught in weekly trappings in four different types of traps in a *Eucalyptus grandis* plantation from June 1997 through June 1998. Means followed by the same letter within each species are not significantly different ($P < 0.05$, Tukey test).

The average values for daily rainfall, average temperature, and minimum temperature were significantly higher in the hot/rainy than in the cool/dry season ($P < 0.05$). Those values were as follows: 2.6 mm, 25.7°C and 18.1°C for the hot season, and 1.3 mm, 22.0°C and 18.1°C for the cool season.

In Brazil, ambrosia beetles fly throughout the year. Therefore, a catch of zero beetles only means they were not trapped, and not that there were no active beetles flying. However, the majority of species are more active during the hot/rainy season (Flechtmann et al. 1995). This was also true for all species in this experiment, except *H. eruditus* which were more abundant during the cold/dry season (data not shown).

There was a statistically significant trap*season interaction for *C. heveae, H. eruditus, P. cavipennis, X. affinis, X. ferrugineus,* and 'other Scolytidae' ($P < 0.05$). This was mainly the result of low catches for these species during the season where they are not too particularly abundant, resulting in catches statistically not significant for the majority (if not all) of the traps.

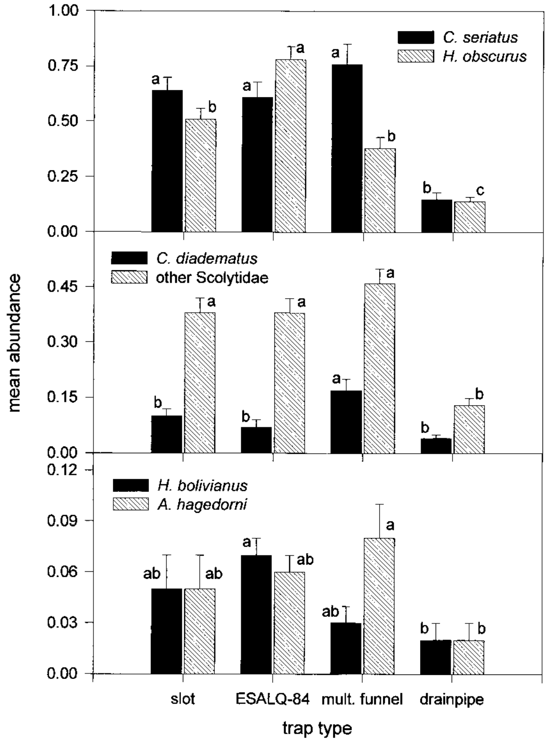

Fig. 3. Mean ± SE numbers per trap of Scolytidae caught in weekly trappings in four different types of traps in a *Eucalyptus grandis* plantation from June 1997 through June 1998. Means followed by the same letter within each species are not significantly different ($P < 0.05$, Tukey test).

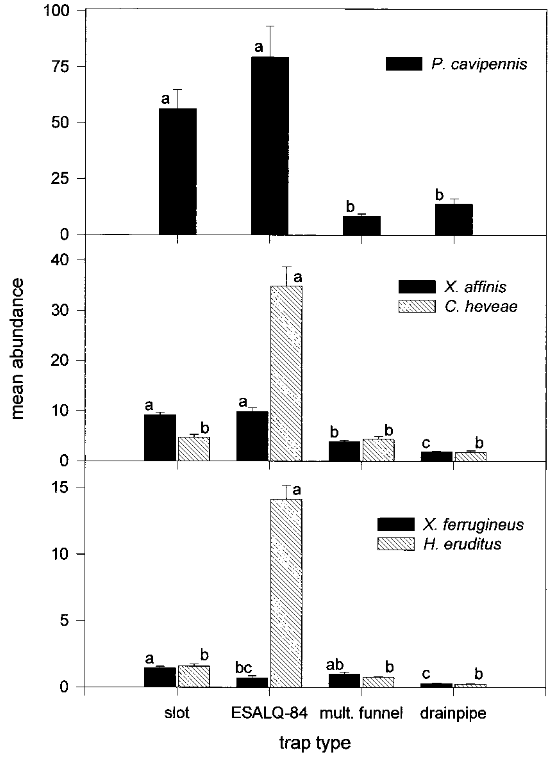

Fig. 4. Mean ± SE numbers (× 10,000) per cm^2 of trapping surface, of Scolytidae caught in weekly trappings in four different types of traps in a *Eucalyptus grandis* plantation from June 1997 through June 1998. Means followed by the same letter within each species are not significantly different ($P < 0.05$, Tukey test).

However, when analyses comparing trapping numbers among traps were performed within each season, results were quite similar to those previously shown, when season was treated as a fixed factor.

When the trapping numbers were corrected for surface area, results were quite different.

For most species, the ESALQ-84 trap caught significantly more beetles than the other trap types (Figs. 4 and 5). *P. cavipennis* and *X. affinis* were trapped equally well in the slot and ESALQ-84 traps, whereas *X. ferrugineus* was trapped in highest numbers in the slot and multiple funnel traps (Fig. 4). There was a significant ($P < 0.05$) trap*season interaction for *C. heveae, C. seriatus, H. eruditus, P. cavipennis,* and *X. affinis.* When trap comparison for those species was attempted for each season, however, results were similar to those observed when all 52 wk of trapping data were considered ($P < 0.05$).

Discussion

Because there was a difference in effectiveness among traps depending on the scolytid species trapped, surveys in Brazil could be improved if the most effective traps were used for those species considered to be most important.

The drainpipe trap was the least effective design tested. These results agree with those obtained by McLean et al. (1987) for *Trypodendron lineatum* (Olivier), when evaluating slot, drainpipe, and multiple funnel traps. This type is a combination of a landing and a flight impact trap; beetles are trapped as they bounce off the pipe and fall through the funnel into the collecting jar and as they land and enter any of the holes in the pipe (Bakke et al. 1983, Byers 1992). Flying beetles bumping into the traps often drop distances of 100 cm or more before reaching the funnel, perhaps enabling many to spread their wings and escape. This factor, in addition to the multiple steps necessary for landing beetles to be trapped (Niemeyer et al. 1983, McLean et al. 1987), possibly contributed to the low capture efficiency of this trap.

The multiple funnel, slot, and ESALQ-84 traps are flight intercept traps only. Beetles attracted by the bait bump into the trap and fall passively into the collecting receiver (Niemeyer et al. 1983, McLean et al. 1987). In comparison to the drainpipe trap, the beetles that collide with these traps drop shorter distances into the collecting vial. This is not absolutely true for the multiple funnel trap, but it seems that the act of the beetle bouncing through all the funnels during its fall would prevent it from spreading its wings until it reaches the

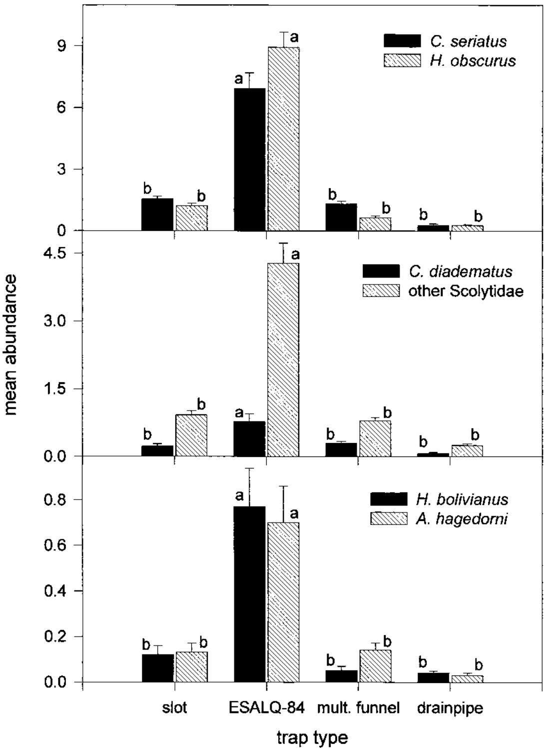

Fig. 5. Mean ± SE numbers (× 10,000) per cm^2 of trapping surface, of Scolytidae caught in weekly trappings in four different types of traps in a *Eucalyptus grandis* plantation, from June 1997 through June 1998. Means followed by the same letter within each species are not significantly different ($P < 0.05$, Tukey test).

collecting vial. These factors might explain overall higher trappings in these types of traps than the drainpipe trap.

Several scolytids, mainly bark beetles, are known to respond to a vertical profile (Billings et al. 1976, Byers et al. 1989, Byers 1995). Only two of the four traps used presented a typical vertical silhouette, the drainpipe and the multiple funnel traps (Fig. 1). Only one species in our study, *C. diadematus* (Fig. 3), was caught in higher numbers in traps displaying a vertical silhouette. *Cryptocarenus* typically attack small cut or stressed stems of small diameter stems of lianas, shrubs, or trees (Wood 1982); therefore, the vertical silhouette might not have been the main factor that resulted in higher catches of *C. diadematus* in the multiple funnel trap. However, the remaining species showed either preference for a trap with no clear profile (*H. bolivianus, H. eruditus, H. obscurus, P. cavipennis,* and *X. affinis*) or showed only a nonpreference for the drainpipe trap (*A. hagedorni, C. heveae, C. seriatus, X. ferrugineus,* and 'other Scolytidae') (Figs. 2 and 3). Most of the species studied in this experiment exhibited behavior similar to that observed by Samaniego and Gara (1970) in *Xyleborus* spp., which showed no preference for any particular trap profile.

Comparisons made after correcting for trap surface area showed that significantly more of the majority of the species analyzed were trapped by the ESALQ-84 trap (Figs. 4 and 5). *X. ferrugineus* was the only species that presented similar results regardless of the way analyses were done (Figs. 2 and 4). The ESALQ-84 trap had the smallest surface area tested, and therefore caught the highest numbers of beetles per unit area. Such behavior was reported for *Dendroctonus brevicomis* LeConte trapped in cylindrical sticky traps of different sizes (Tilden et al. 1979).

Trap efficacy is, however, directly influenced by the bait release rate (Lindgren et al. 1983). Therefore, we could assume the previously discussed relationship between trap surface area and beetle trapping to hold true only if the ethanol release rate is the same for all trap types. Although the dispensers were all the same, they were more or less exposed to the open environment, depending on the trap type. The ranking of degree of exposure of the dispenser to the environment, from the least to the most exposed, was as follows: drainpipe, slot, multiple funnel, and ESALQ-84 traps. In one extreme we had a dispenser placed inside a totally closed pipe, from where the kairomone ethanol could escape only through the multiple little holes drilled through the drainpipe trap wall; whereas on the other extreme there was a dispenser nearly totally exposed to the environment, as in the ESALQ-84 trap.

The temperature inside the drainpipe trap can get higher than the air temperature, leading to an increase in the release rate of the semiochemical (Bakke et al. 1983), which could also apply, to a lesser degree, to the slot trap. There is usually a positive correlation between ethanol release rate and response of ambrosia beetles (Samaniego and Gara 1970); therefore, especially for the drainpipe trap, either the presumably higher release rate might not change significantly enough to affect beetle behavior, the design of the trap does not favor ambrosia beetle trapping, or the diffusion of the volatilized ethanol from the pipe to the environment is inefficient. However, there were semiochemicals placed in dispensers more exposed to the environment, which was the case for the ESALQ-84 and to a lesser extent for the multiple funnel trap as well. In these two cases, the release rate could also have been increased because of the wind, perhaps reaching levels similar to dispensers placed in more closed spaces. A higher efficiency of diffusion of ethanol to the environment associated with a design better fit for capturing ambrosia beetles in flight could explain a higher beetle catch per unit area in the ESALQ-84 trap. Conversely, possibly a low bait diffusion to the environment and a less efficient design for the drainpipe traps could explain its low beetle catches. However, weekly ethanol release rates have to be measured to support any of the stated hypotheses.

Lanier et al. (1976) found that trappings of *Scolytus multistriatus* (Marsham) on square sticky traps resulted in identical numbers of beetle per trap unit area as the trap surface area increased. If the scolytid beetles analyzed in this experiment behaved more like *S. multistriatus* than *D. brevicomis,* then the highest catches per unit surface area observed in the ESALQ-84 trap would likely be caused by a higher bait release rate.

Further experiments are necessary to determine if the higher catches per unit of trap surface area are the result of the trap surface area, a difference in bait release or even a combination of any of these factors with the trap type. Until the reasons for a higher efficacy of the ESALQ-84 trap based on surface are conclusively determined, it is safer to base recommendation on trap use on comparisons of absolute numbers of beetles caught on each trap type.

Most (>97%) of the scolytid beetles trapped were in the genera *Cryptocarenus, Hypothenemus, Premnobius,* and *Xyleborus.* Of those species in the genera, *Hypothenemus* and *Cryptocarenus* usually attack host material of small dimensions (Wood 1982) and would be considered only a minor threat to eucalypt plantations. *P. cavipennis* is the scolytid most frequently associated with *Eucalyptus* plantations in Brazil north of the Tropic of Capricorn (≈23° latitude south) (unpublished data). It was by far the most abundant species trapped (≈67% of the total), and it is reported to attack live eucalypts and cause economic damage. *X. affinis* and *X. ferrugineus* are two of the most aggressive ambrosia beetle species in Brazil and other tropical regions (Beaver 1988, Pedrosa-Macedo 1988; unpublished data), and reported to attack live eucalypts as well (J. C. Zanuncio, personal communication). Therefore, monitoring and eventually control efforts in *Eucalyptus* plantations should be concentrated basically on three species: *P. cavipennis, X. affinis,* and *X. ferrugineus.*

The slot trap (Fig. 2) caught significantly more representatives of these three most important eucalypt scolytid beetles and would most likely be recommended for monitoring scolytid beetles in sites similar to those encountered in these tests.

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