Effect of Organic and Inorganic Landscape Mulches on Subterranean Termite (Isoptera: Rhinotermitidae) Foraging Activity

CATHERINE E. LONG,[1] BARBARA L. THORNE, NANCY L. BREISCH, and LARRY W. DOUGLASS

Department of Entomology, University of Maryland, 4112 Plant Science Building, College Park, MD 20742

Environ. Entomol. 30(5): 832–836 (2001)

ABSTRACT This research investigated whether organic and inorganic landscape mulches, which buffer soils against temperature extremes and desiccation, create conditions conducive to subterranean foraging by *Reticulitermes virginicus* (Banks). In the field, termite activity was measured with cardboard monitors placed beneath and within plots of eucalyptus, hardwood, pine bark, and pea gravel mulches, and bare ground (control). Gravel mulch provided higher feeding rates in underground monitors. Groundcover type had no significant effect on the number of monitors discovered by termites or the number of termites within each monitor. All groundcovers significantly reduced the temperature of the soil surface compared with bare soils, but temperature and moisture levels 12 cm below mulch-covered surfaces were not significantly different from those beneath bare soil. In the laboratory, *R. virginicus* were fed one of the three organic mulches or a control diet of white birch, *Betula papyrifera* (Marsh), as their only food source. All diet types were consumed at equivalent rates, but the mulch-fed termites suffered significantly lower survivorship.

KEY WORDS *Reticulitermes*, subterranean termites, landscape mulch, foraging

Organic and inorganic mulches, which include bark and wood products, pine needles, nut and grain hulls, leaves, plastics, recycled carpeting, tar paper, shredded tires, and gravel (Bennet 1982, Kraus 1998, Nardozzi 1998), are effective soil amendments in part because they conserve soil moisture and insulate against temperature extremes (Fraedrich and Ham 1982). Groundcovers conserve moisture by reducing evaporative water loss from the underlying soil (Del Tredici 1992, Smith and Rakow 1992) and by preventing soil surface encrusting, thus allowing precipitation to better filter into the soil (Groenevelt 1989). The structural complexity and solar reflectivity of mulches account for a portion of their insulating properties. Air trapped within the mulch matrix provides an insulating buffer between the soil and the outside air (Harris 1983). Inorganic mulches tend to be less insulating than organic ones (Borland 1990), but their typically greater solar reflectivity cause them to heat more slowly than organic products, which are generally darker in color (Kemper 1994).

Conventional wisdom has long held that inorganic groundcovers are inherently unattractive to termites and discourage harborage by speeding soil drainage and drying (NPMA 1999, Lyon 2000). Conversely, organic mulches are thought to attract foraging termites both because of their potential as a food source and because of the temperate, moist conditions they create in the underlying soil. Considering that subterranean termites cause an estimated $5 billion worth of structural damage annually in the United States (NPMA 1999), and that mulch groundcovers are ubiquitous in the urban and suburban landscape, we examined the validity of these common assumptions.

In the field, we studied the effects of one inorganic and three organic mulches on the foraging pattern of *Reticulitermes virginicus* (Banks) and on associated abiotic conditions in the underlying soil. In the laboratory, we tested three organic mulches as food resources for *R. virginicus* by measuring the quantity of mulch consumed by workers during a 9 wk feeding trial and by calculating the weekly survivorship of those insects.

Materials and Methods

Field Foraging Research

Field Site Design. To assess the impact of mulches on the foraging activity of *R. virginicus,* five sites were established in Prince George's County, MD, on properties belonging to the University. The mulch beds were situated adjacent to structures and surrounded by lawns. Woodlands containing a mix of oaks, hollies, and maples were located within 25 m of each site. At each site, all existing sod, ornamental grasses, and decorative groundcovers were removed and the soil was raked smooth and level.

The sites were divided into four complete randomized blocks. Each block contained four varieties of groundcover and a control plot of bare earth. Plots were separated from each other by 15 cm border

[1] E-mail: cmall@wam.umd.edu.

strips. Shredded hardwood bark and miniature pine bark nuggets were included in the study because of their wide availability and popularity; shredded eucalyptus bark was chosen because it is advertised as being resistant to "common lawn and garden pests" (A-Action 1997). Pea gravel (0.5–3.0 cm-diameter) was selected for its widespread use along pathways and roof drip lines. Mulches were applied to a depth of ≈7 cm of mulch in accordance with National Gardening Association recommendations (Nardozzi 1998). Bare earth served as the control treatment.

Treatment plots were delineated by 40 by 40 by 9-cm lattice-bottomed greenhouse flats (Wetsel, Harrisonburg, VA). The open-work flats allowed the mulches complete contact with the soil while enabling us to lift entire treatments to observe the soil surface. Previous research indicates that objects on the surface as small as 8 cm in diameter can significantly impact moisture and temperature conditions in underlying soils (Benoit and Kirkham 1963, Corey and Kemper 1968, Ettershank 1980, Groenevelt et al. 1989, Smith and Rust 1994, Kemper et al. 1994). In 1998, three sites were set up beginning in June and monitored until November. In May 1999, the original mulch was replaced with fresh material at the three existing sites and two additional sites were created. All five were monitored until October.

Measuring Termite Activity. Corrugated cardboard monitoring stations buried underground and within the mulch layer were used to gather three types of foraging data: the number of monitors discovered by foragers, the number of termites observed within a monitor, and the quantity of cardboard consumed from a monitor (LaFage et al. 1973, Johnson and Whitford 1975). Underground monitoring stations were formed by rolling 12 by 60-cm strips of cardboard into tight 6-cm-diameter cylinders. The cylinders were inserted into holes (12 cm deep by 6 cm diameter) excavated beneath each treatment plot using a 6 cm auger bit mounted on a hand drill. Sleeves of flexible, 1-cm plastic mesh stabilized the excavated holes. Stacks of four 8-cm squares of cardboard were buried in the mulch to assess foraging within the mulch media.

Monitors were removed every 3 wk and replaced with fresh cardboard. Termites were counted in the field and returned immediately to the same hole in the ground. Cardboard monitors with evidence of termite feeding and frass deposition were returned to the lab, cleaned, oven-dried (44°C for 7 d), and weighed. Unoccupied monitors with no signs of termite feeding were discarded. All monitors with evidence of feeding were classified as discovered. Cardboard consumption was calculated by subtracting the postfeeding weight from the initial weight.

Statistical analyses of all field and laboratory data were performed using mixed model analysis of variance (ANOVA, SAS Institute 1996). Repeated measures analyses were used where appropriate and heterogeneous variance problems were addressed by variance partitioning. Differences among significant treatment effects ($P > 0.05$) were determined with least square means. To achieve the most sensitive test of differences, we pooled all the data rather than analyzing 1998 and 1999 separately. However, high site by year interaction effects necessitated that we interpret the results for eight site-year combination years rather than averaging data from the five sites.

Measuring Abiotic Soil Conditions. Abiotic conditions in the soil underlying the mulch plots were measured every 10 d. Soil moisture levels 12 cm beneath the surface of each treatment were measured with Watermark gypsum monitors (Irrometer, Riverside, CA) (Carlson and El Salem 1987). Temperatures at both the mulch-soil interface (the soil surface in a control plot) and at 12 cm below the soil surface were recorded with thermocouple thermometers (Hanna Instruments, Padova, Italy) (Benoit and Kirkham 1963). To reduce the influence of partial shading on physical conditions across a site, recordings were made after a site had experienced uniform solar exposure for at least an hour.

Laboratory No-Choice Feeding Research. To gauge *R. virginicus'* ability to use organic mulches as a food source, we measured the quantity of each type of mulch that *R. virginicus* workers consumed over a 9-wk period and the survivorship rate of those termites. Termites from three separate colonies were collected from Maryland and Georgia and maintained in the laboratory on a diet of moist cardboard and decayed white birch, *Betula papyrifera* (Marsh), before experimentation. Five experimental repetitions were performed with each colony. Batches of 200 workers were placed in 9-cm-diameter plastic petri dishes containing moist, sterile sand and equivalent volumes of one of four treatment diets: white birch (control), hardwood, eucalyptus, or pine bark mulch. White birch, which *Reticulitermes* feed upon readily, was used to gauge the consumption rate of a palatable food under laboratory conditions. Food resources were replenished throughout the experiment as they were depleted. A second, starvation control was run in which the termites were provided with only moist sand.

Termite survivorship was calculated by counting the number of living termites every 7 d. Dead individuals were removed from the dishes. To account for the decreasing number of termites over the duration of the experiment, we averaged the number of living termites in each dish per week. Total mulch consumption was calculated at the end of 9 wk by subtracting the final weight from the initial weight of each diet sample. Standardized mulch consumption values were determined for each dish by dividing the total consumption by the sum of the average number of termites alive per week.

Results

Field Foraging Results

Termite Activity. Groundcover type (organic or inorganic mulch or bare earth control) had no significant effect on the number of cardboard monitors discovered or occupied by foraging termites either within the mulch or in the underlying soil, nor did

Table 1. ANOVA results of *R. virginicus* foraging activity as measured by cardboard monitoring stations

Monitor placement	Activity parameter	*F* ratio	df	*P*
Underground	Monitors discovered	2.08	4,16	0.1318
	Cardboard consumed (g)	5.58	4,16	0.0052
	Termites observed	0.38	4,16	0.8201
Within-mulch[a]	Monitors discovered	1.79	3,15	0.1923
	Cardboard consumed (g)	1.70	3,15	0.2095
	Termites observed	0.17	3,15	0.9162

[a] Within-mulch activity monitors were not placed in the control plots; the presence of a monitor on the soil surface would confound results from the bare earth control.

Table 2. ANOVA results of abiotic conditions in the underlying soil

Measurement location	Physical condition	*F* ratio	df	*P*
Soil surface	Temp, C°	10.34	4, 28	0.0001
Soil subsurface (12 cm deep)	Temp, C°	1.31	4, 28	0.2888
	Moisture (centibars[a])	1.89	4, 28	0.1404

[a] Saturated soil has a centibar value of 0; values increase as soil dries.

mulch type significantly impact the quantity of cardboard consumed from the within-mulch monitors. Groundcover had a significant impact on the quantity of cardboard consumed by the termites from the underground monitors, with the highest consumption observed beneath the pea gravel ($P = 0.0052$; df = 4,16) (Table 1; Fig. 1). Temperatures at the soil surface were significantly higher in the bare earth control treatments than in those covered by mulch ($P = 0.0001$, df = 4, 28). Subsurface soil temperature and moisture 12 cm deep were not significantly impacted by groundcover type ($P = 0.2888$ df = 4, 28; $P = 0.1404$ df = 4, 28) (Table 2; Fig. 2).

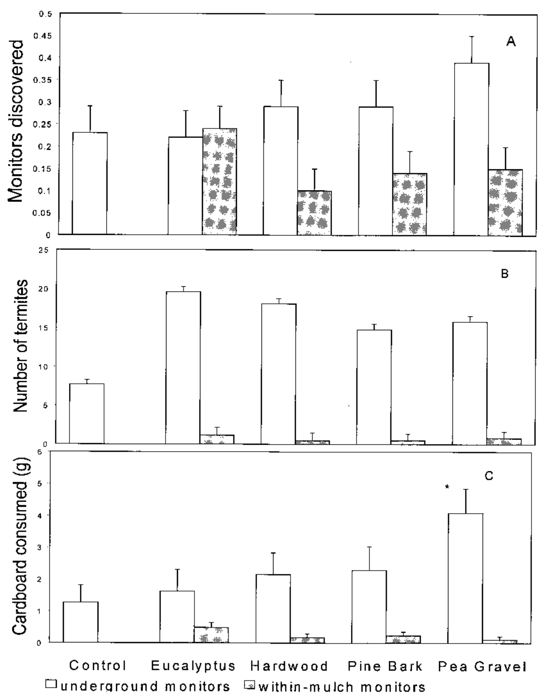

Fig. 1. Foraging activity within mulches and in the underlying soil as measured by (A) the number of cardboard monitoring stations discovered by termites, (B) the number of termites observed within the monitors, and (C) the quantity (g) of cardboard consumed from the monitors. Error bars are standard errors of the mean. The asterisk (*) denotes a mean significantly different from the control ($P < 0.05$)

Laboratory No-Choice Feeding Results. Diet type did not significantly impact the quantity of material consumed per termite-week; organic mulches and the control diet were eaten at equivalent rates. Termites fed on an organic mulch diet and those denied food survived at equivalent rates which were significantly lower than the survivorship of insects fed on the control diet (Table 3; Fig. 3).

Discussion

Although termite activity within underground cardboard monitors demonstrated that the insects discovered and harbored within the monitors with equal likelihood, sustained activity over time, as estimated by total consumption of cardboard, was significantly

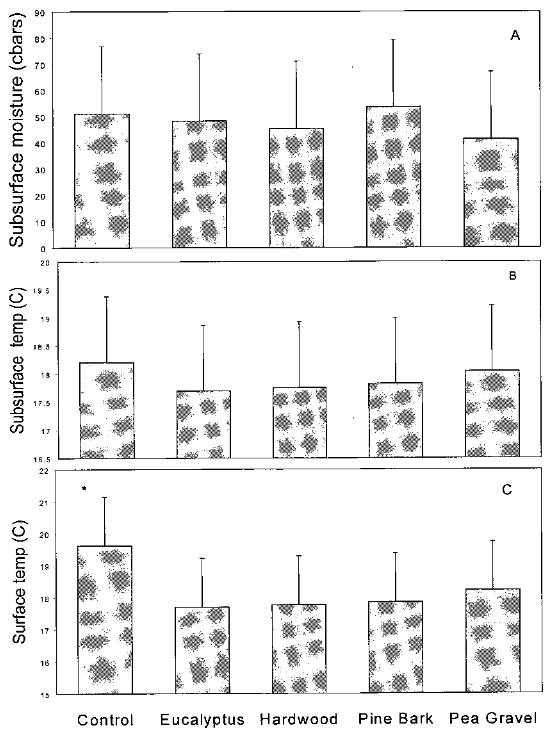

Fig. 2. (A) Moisture in the soil subsurface (12 cm deep), (B) temperature at the soil subsurface (12 cm deep), and (C) temperature at the soil surface. Error bars are standard errors of the mean. The asterisk (*) denotes a mean significantly different from the control ($P < 0.05$).

Table 3. ANOVA results of 9-wk no-choice feeding trial

Parameter	*F* ratio	df	*P*
Quantity of diet consumed, mg	3.12	3, 6	0.1096
Termite survivorship/week	59.33	4, 8	0.0001

higher beneath the gravel mulch treatments. Within-mulch termite activity confirmed that the insects travel within both organic and inorganic media, confirming Forschler's (1998) caution that mulches may provide a bridge across soil termiticide barrier treatments.

Despite widespread precedent for mulched soils to be buffered against temperature extremes and to conserve moisture more effectively than bare soils (Fraedrich and Ham 1982, Harris 1983, Smith and Rakow 1992, Del Tredici 1992), groundcover type did not significantly affect either temperature or moisture level in the soil 12 cm below the surface. Temperature at the soil surface, however, was significantly cooler beneath all four types of mulch than at the surface of bare control soils. Our findings confirm those of Smith and Rust (1994) and Ettershank et al. (1980), who evaluated the impact of thermal shadows cast by objects on the soil surface on termite foraging patterns. Smith and Rust (1994) concluded that shadows cast by objects cast by objects as small as 30 by 30-cm may provide a cool refuge where termites prefer to forage during the heat of the day.

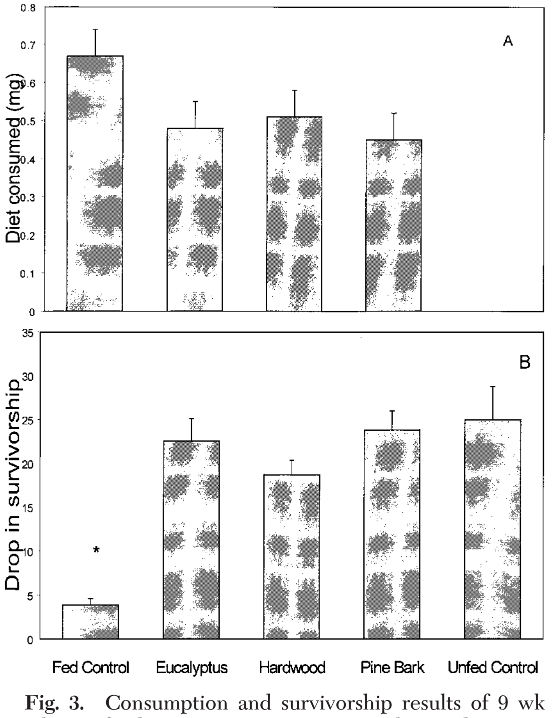

Fig. 3. Consumption and survivorship results of 9 wk no-choice feeding experiment. (A) No-choice diet consumed (mg) per termite-week; diet type had no significant effect on the quantity of material consumed. (B) Drop in weekly survivorship. Diet type had a significant impact on rate of termite survivorship. Error bars are standard errors of the mean. The asterisk (*) denotes a mean significantly different from the control ($P < 0.05$).

The fact that termite cardboard consumption was significantly impacted by only pea gravel mulch suggests that subsurface temperature is not the only factor influencing feeding patterns. Haagsma and Rust (1995) predicted that when temperatures are within acceptable bounds, moisture likely influences preferred foraging locations. Corey and Kemper (1968) concluded that gravel mulches should increase soil moisture content by increasing water infiltration and, unlike porous mulches, by not absorbing water themselves. Our data show a trend for higher moisture levels below the gravel mulches, although the difference was not significant compared with the other groundcovers. More definitive differences might have been apparent if moisture levels had been recorded at a shallower depth, within the cool subterranean shadow cast by the mulches.

In the laboratory feeding experiment, diet type did not significantly affect the rate of material consumption per termite week, but the mulch-fed termites experienced significantly lower survivorship. A lack of significant differences between the survivorship of mulch-fed and starved termites suggest that although the mulch-fed termites were actively feeding, they derived inadequate nutrition from the mulches. If the mulches contained toxins, we would have expected the termites to experience lower survivorship than starved nestmates. Many barks contain a high percentage of lignin (Rowell 1984). Studies are inconclusive regarding termites' ability to use lignin; termites appear to eat it but incorporate little carbon from its tissues, suggesting that lignin is either not used as an energy source or is metabolized quickly (reviewed in Waller and LaFage 1986).

High consumption observed in the underground monitors below the inorganic pea gravel units may suggest that the termites consumed the overlying organic mulch when available instead of the monitors. This seems unlikely in light of the mulches' apparent inadequacy as food sources in the laboratory. Further, if the same level of termite activity seen below ground had occurred in the mulch, tubing and structural modifications would have been evident at the soil-mulch interface. Such structures were absent.

Our data provide no indication that landscape mulches increase the rate of initial scouting in an area. However, our research suggests that gravel mulches create a hospitable environment where termites are likely to spend more time feeding on resources such as roots, stumps, or construction debris than they would if these resources were buried beneath either organic mulches or bare ground. Our results also infer that installing termiticide bait or monitoring stations beneath inorganic mulch beds is unlikely to increase the chance that the stations will be discovered by foragers, but this placement might increase the duration of feeding experienced by those stations once they have been found by the foragers.

Because it is rare that structure-infesting *Reticulitermes* colonies exist in isolation from the surrounding soils, we believe that efforts to make the soils surrounding structures as inhospitable as possible may decrease the likelihood that those structures will experience initial or maintain existing termite infestations. Unless interior water resources, such as leaking plumbing connections, are available, foragers maintain a connection to the exterior soil to gather moisture. Although colonies can be wholly contained within a building, most structure-infesting termites constitute just a portion of a larger colony network that may forage across several acres of land. Therefore, most structure-infesting termites are traveling through and are affected by the soil surrounding a building's foundation.

We caution against placing beds of pea gravel at least 40 cm wide directly against a foundation. If material must be placed close to the structure for esthetic purposes, we recommend spreading a single layer so that soil drying is less hindered.

Acknowledgments

We thank Jeff Long, Debbie Finke, Darla McDonald, and Sara Ferguson for assistance collecting and processing cardboard samples and Mark Suarez for collecting termites from Georgia. We thank the Central Maryland Research and Educational Center in Upper Marlboro and the University of Maryland Astronomy Observatory for access to their properties, and the University grounds crews for their attention to the field sites. This work was completed in partial fulfillment for the requirements of a Master of Science by C.E.L. at the University of Maryland at College Park.

References Cited

A-Action Mulch of Southwest Florida. 1997. The professional's choice (http://www.aactionmulch.qpg.com).

Bennett, J. 1982. Mulches to retain moisture and cool the soil. Horticulture 60(7): 55–56.

Benoit, G. R., and D. Kirkham. 1963. The effect of soil surface conditions on evaporation of soil water. Soil Sci. Soc. Proc. 27: 495–498.

Borland, J. 1990. Mulch; examining the facts and fallacies behind the uses and benefits of mulch. Am. Nurseryman 172(4): 132–143.

Carlson, T. N., and J. El Salem. 1987. Measurement of soil moisture using gypsum blocks, pp. 193–199. Proceedings of International Conference on Measurement of Soil and Plant Water Status. Utah State University, Logan, UT.

Corey, A. T., and W. D. Kemper. 1968. Hydrology papers, no. 30: conservation of soil water by gravel mulches. Colorado State University, Ft. Collins, CO.

Del Tredici, P. 1992. Make mine mulch. Arnoldia 53(3): 30–32.

Ettershank, G., J. A. Ettershank, and W. G. Whitford. 1980. Location of food sources by subterranean termites. Environ. Entomol. 9: 645–648.

Forschler, B. T. 1998. Subterranean termite biology in relation to prevention and removal of structural infestation. *In* NPCA research report on subterranean termites. NPCA, Dunn Loring, VA.

Fraedrich, S. W., and D. L. Ham. 1982. Wood chip mulching around maples: effect on tree growth and soil characteristics. J. Arboric. 8(4): 85–89.

Groenevelt, P. H., P. van Straaten, V. Rasiah, and J. Simpson. 1989. Modifications in evaporation parameters by rock mulches. Soil Tech. 2: 279–285.

Haagsma, K. A., and M. K. Rust. 1995. Colony size estimates, foraging trends, and physiological characteristics of the western subterranean termite (Isoptera: Rhinotermitidae). Environ. Entomol. 24: 1520–1528.

Harris, R. W. 1983. Arboriculture: care of trees, shrubs, and vines in the landscape. Prentice-Hall, Englewood Cliffs, NJ.

Haverty, M. I., J. P. LaFage, and W. L. Nutting. 1974. Seasonal activity and environmental control of the subterranean termite, *Heterotermes aureus* (Snyder), in a desert grassland. Life Sci. 15: 1091–1101.

Johnson, K. A., and Whitford W.G. 1975. Foraging ecology and relative importance of subterranean termites in Chihuahuan desert ecosystems. Environ. Entomol. 4: 66–70.

Jones, S. C., M. W. Trosset, and W. L. Nutting. 1987. Biotic and abiotic influences on foraging of *Heterotermes aureus* (Snyder) (Isoptera: Rhinotermitidae). Environ. Entomol. 16: 791–795.

Kemper, W. D., A. D. Nicks, and A. T. Corey. 1994. Accumulation of water in soils under gravel and sand mulches. Am. J. Soil Sci. Soc. 58: 56–63.

Kraus, H. T. 1998. Effects of mulch on soil moisture and growth of desert willow. HortTechnology 8: 588–590.

LaFage, J. P., W. L. Nutting, and M. I. Haverty. 1973. Desert subterranean termites: a method for studying foraging behavior. Environ. Entomol. 2: 954–956.

LaFage, J. P., M. I. Haverty, and W. L. Nutting. 1976. Environmental factors correlated with the foraging behavior of a desert subterranean termite, *Gnathatermes perplexus* (Banks) (Isoptera: Termitidae). Socio. 2: 155–169.

Lyon, W. F. 2000. Ohio State University extension fact sheet; termites (http://www.ag.ohio-state.edu/~ohioline/hyg-fact/2000/2092.html).

[NPMA] National Pest Management Association. 1999. Preventative measures you can take. Pest Gaz. (http://pestworld.org/media/pest-gazette/spring99/article9.html).

[NWS] National Weather Service. 2000. Public information statement; 1999 year end review (http://www.nws.noaa.gov/er/lwx/99review.txt).

Nardozzi, C. 1998. Shoppers' guide to bark mulch. National Gardening Association. South Burlington, VT.

Rowell, R. 1984. The chemistry of solid wood. American Chemical Society, Washington, DC.

Rust, M. K., K. Haagsma, and J. Nyugen. 1996. Enhancing foraging of western subterranean termites (Isoptera: Rhinotermitidae) in arid environments. Sociobiology 28: 275–286.

SAS Institute. 1996. SAS/STAT user's guide, version 6.12. SAS Institute, Cary, NC.

Smith, A. M., and D. A. Rakow. 1992. Strategies for reducing water input in woody landscape plantings. J. Arboric. 18: 165–170.

Smith, J. L., and M. K. Rust. 1994. Temperature preferences of the western subterranean termite *Reticulitermes hesperus* Banks. J. Arid Environ. 28: 313–323.

Waller, D. A. and J. P. LaFage. 1986. Nutritional ecology of termites. *In* F. Slansky and J.G. Rodriguez [eds.], Nutritional ecology of insects, mites, spiders, and related invertebrates. Wiley, New York.

Received for publication 26 October 2000; accepted 12 June 2001.