Laboratory Evaluation of Feeding Preferences of Formosan Subterranean Termites, *Coptotermes formosanus* (Isoptera: Rhinotermitidae), on Cultivars of Pecan, *Carya illinoinensis*, in Texas

by

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ABSTRACT

The feeding preferences of *Coptotermes formosanus* Shiraki were evaluated on the wood of 56 field-collected pecan *Carya illinoinensis* (Wangenh) cultivars. It was evident from this study that Formosan termites had specific feeding preferences among the pecan cultivars evaluated. The 'Moneymaker' cultivar of *C. illinoinensis* was most preferred by *C. formosanus*, and the degree of feeding on this cultivar was significantly different ($P < 0.05$) from all other cultivars tested. 'Creek' was the least preferred cultivar, but the degree of feeding was not significantly different from other cultivars, with the exception of 'Moneymaker'. There was a trend for lower consumption of wood from commercially important versus native cultivars. This suggests that Formosan termites may be differentially attracted to a variety of pecan cultivars and/or chemicals associated with that wood. These results further demonstrate that pecan cultivars are at risk to *C. formosanus* feeding, and that future pecan cultivar selections should take into account this vulnerability.

Key Words: Formosan termites, *Coptotermes,* Pecan, Carya

INTRODUCTION

The economic impact of *Coptotermes formosanus* damage exceeds $1 billion annually as a result of feeding on houses, other buildings, utility poles, railway structures, boats, paper, and living trees (Edwards & Mill 1986; Su & Tamashiro 1987; Su & Scheffrahn 1990). In Texas, a *Coptotermes* species was first discovered in 1956 at the Houston Ship Channel in Pasadena (Harris Co.). The first established *C. formosanus* population in Texas was confirmed

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in Beaumont (Orange Co.), in 1962. By 1967, these termites were found in three states in the continental United States, and are presently established in 15 states, including Hawaii. This species is more destructive than native subterranean termites (*Reticulitermes* spp.) because of the larger colonies and foraging territories (Su & Tamashiro 1987; Su & Scheffrahn 1990; Gold *et al.*1996). In addition, one of the unique characteristics of *C. formosanus* is its propensity to attack living trees. Unlike native termites, *C. formosanus* attacks at least 50 known plant species in the United States. Infestations in living trees often go undetected because of the cryptic and concealed nature of the feeding termites (La Fage 1987).

Infestations of *C. formosanus* weaken trees, often causing them to fall. These close associations with infested trees also threaten urban structures (Osbrink *et al.* 1999). The vast economic and ecological impact of *C. formosanus* has been most evident in the aftermath of hurricanes in the coastal areas of the United States during the past two decades. That is, high winds produced by these storms caused trees to fall due to structural weakening by feeding *C. formosanus*. After hurricane Andrew in 1992, 60% of 360 trees examined in New Orleans were found to be infested with *C. formosanus.* Investigations of coastal trees felled by Hurricane Rita determined that 40% of large trees marked for deposition in landfills were infested with these termites (Mcquaid 2009).

Controlling termites in infested trees is usually accomplished through exposure to slow acting, non-repellent insecticides either as liquids, foams or baits. Termite baits delivered via ingestion depend upon the consumption of the bait by the termites (Grace *et al.* 1996). Because of the aggressive foraging and feeding on cellulose by *C. formosanus,* termite baits could provide effective management. However, control of termites in pecan trees has several additional factors that confound control efforts. First, there are no insecticides labeled to treat the interior of nut or fruit bearing trees. Second, available treatments such as slow-acting baits may take months, years or may never achieve control (Glenn and Gold, 2003). Third, the termite bait matrix may not induce termites to feed when in the presence of optimal alternative food sources. Termites tend to ignore baits when an optimal food source, like pecan, is present (Morales-Ramos and Rojas, 2001). Fourth, the bark patterns on most pecan trees make detection via visual identification of termite infestations very difficult. That is, pecan bark morphology prevents rapid inspection for the presence of *C. formosanus* mud tubes formed on the outside of a tree, mud filled pruning scars, or the presence of termites at the base of a tree. Other methods of identifying termite infestations include audio/acoustic and movement sensory devices, but these are expensive and not readily available. Tests by Morales-Ramos and Rojas (2001) identified several preferred wood species, and pecan was clearly shown to be highly favored by Formosan termites based on the growth and survival of incipient colonies (Morales-Ramos & Rojas, 2001).

The objective of our research was to determine whether *C. formosanus* would demonstrate feeding preferences on wood of different pecan cultivars. Determination of *C. formosanus* consumption rates among cultivars was used to evaluate whether cultivars were at high or low risk to termite feeding.

MATERIALS AND METHODS

Colony collection and culturing

Coptotermes formosanus colonies were collected from three different locations. Two collection sites were located in Baytown, TX (29.73'32, 80"N, 94.97'70, 64"W) and (29.73'59, 98"N, 94.99'69, 45"W), and one in Beaumont, TX (30.04'07, 15"N, 94.06'85, 46"W). Colonies were collected with the use of in-ground wood blocks made of southern yellow pine (*Pinus taeda* L.). Three wood blocks, 2.54 x 15.2 x 15.2 cm, were connected by running all-thread rod (9 cm in length and 0.6 cm in diameter) through a 0.6 cm hole drilled in the center of each block. The blocks were then held in place by using wing nuts to attach both ends of the all-thread rod to form the feeding substrate. The assembled blocks were housed in a 3.8 m^3 plastic bucket, with the bottom removed to allow the block to have direct contact with the soil. A hole was dug in the soil to accommodate the size of the bucket, and then the wooden blocks were placed in the center. The lid of the bucket was then placed on top, and covered with soil. This trap was left in the ground for a period of 1 month before being checked for the presence of *C. formosanus*. After termites were found in the traps, the blocks were removed and placed in individual 3.8 m^3 buckets and brought back to the laboratory where they were stored at room temperature until sorting. After a period of no more than 3 d, the termites were tapped out of the blocks onto a plastic sorting tray. The sorting device consisted of a 40.50 x 30.50 cm plastic tray tilted at a 20° angle which allowed the termites to move downward. At the bottom of the plastic tray, six 0.60 cm holes spaced 3.8 cm apart were connected to plastic tubing (0.60 cm in diameter and 7.60 cm in length). Through the tubes, termites dropped into a 33.00 x 19.10 x 11.40 cm acrylic plastic shoe box (Pioneer Plastics®, USA Highway 41A North, Dixon Kentucky, 42409). Professional Choice® tongue depressors (15.2 cm) (Solon Company, Skowhegan, Maine, 04976) were soaked in water for 1 h to saturate them and leach out soluble chemicals. They were then placed on paper towels to dry for 5 minutes, and then cut into 3.80 cm pieces, and stacked in a 14.25 cm Petri dish (Nagle Nunc International, 75 Panorana Creek Drive, Rochester, New York, 14625). The 3.80 cm wood pieces were stacked in the Petri dish, one on top of the other, in a horizontal pattern. Two 7.60 cm pieces of tongue depressor were placed on top of the arrangement, to form a square. Two additional pieces were placed in the center as fillers. This pattern was continued until the depressors were stacked four rows high. These Petri dishes served as the standard culturing arenas. The termites were gently removed from the sorting system, and placed in the arenas, covered with lids, and stored in an environmental chamber at 29.4 ± 2°C and 85 ± 4% RH until initiation of the study.

Pecan wood collection and preparation

Cultivars were selected based on historical and commercial importance (Thompson and Young, 1985). Pruning shears were used to cut branches (cross-sections contained bark and heartwood) measuring 22.31 ± 3.48 cm in length and 2.52 ± 0.34 cm in dia, from 56 pecan cultivars (*Carya illinoinensis*), grown at the USDA Pecan Breeding and Genetics Program in Somerville, TX (30.31' 20,61"N , 96.25', 24,64"W). The wood samples were then placed in labeled Zip Loc® bags and brought back to the laboratory where they were stored at room temperature (25 ± 2°C and 55 ± 4° RH). These samples were then cut on a band saw using a fence to ensure that all were approximately 0.42 cm thick. These samples were then dried in a Fisher Scientific Isotemp oven (Fisher Scientific 2000 Park Lane Drive Pittsburgh, PA 15725) at 51° C for 8 hrs. After drying, they were allowed to cool to room temperature (25° ± 2° C), weighed to the nearest 0.1 mg, labeled and stored in labeled plastic bags until initiation of the experiments. These steps were taken in order to record a pre-feeding dry-weight for each wood wafer. At the initiation of the experiments, the wood wafers were individually rehydrated by placing them in a 100 ml glass beaker containing 50 ml of distilled water. Each wafer was allowed to soak for 5 minutes, after which they were placed in individual Petri dishes. Each Petri dish contained 95.1 g of sand and 20 ml of water to provide moisture to preserve the termites.

Introduction of termites

Termites were removed from the environmental chamber 1 wk prior to testing to allow them to acclimate to laboratory conditions. A total of 250 termites were hand counted (25 of which were *C. formosanus* soldiers) and placed in Petri dishes containing hydrated sand. In nature, Formosan termite soldiers make up 5 to 15% of a termite colony, therefore 25 soldiers were used in this study since foraging behavior is dependent upon the numbers of soldiers present in the colony (Mao, *et al.* 2005). Termites were placed in a single Petri dish with a single wood wafer. After *C. formosanus* were added to the Petri dish arenas, a lid was placed on top to retain the termites, and to keep the wood wafers moist. Untreated controls consisted of an arena containing a wood wafer with no termites, but prepared as described above with moist sand. This non-treated control was used to provide data regarding wood weight gain or loss in the treatment arenas. Additional untreated controls, each containing 250 termites, utilizing the standard culturing arena design, were placed in proximity to the testing array. These controls were monitored through time to estimate normal termite mortality. This experiment was replicated three times. The study was conducted in a darkened laboratory at 25 ± 2° C and 55 ± 4% RH and ran for 8 d. After 8 d had elapsed the wood wafers were removed, cleaned, dried and reweighed to determine the post-feeding dry-weight. This weight was then compared to the pre-weight to determine the amount of wood consumed by the termites.

Statistical data analysis

These experiments were designed to test the null hypothesis that *C. formosanus* would not show a significant preference for the wood of different pecan cultivars. General Linear Model (GLM) was used to analyze the data and Tukey's Honestly Significant Difference (HSD) was used to separate means ($P < 0.05$) (SPSS v. 16.0.1).

RESULTS

Consumption of wood wafers by *C. formosanus* differed significantly ($F = 15.49$; $df = 59,240$; $P < 0.05$) based on GLM analysis of the 56 cultivars tested. The range of wood mass consumed by the termites was 0.017 to 0.637 g for the 'Creek' and 'Moneymaker' cultivars, respectively (Table 1). 'Creek' was the least preferred cultivar, while 'Moneymaker' was the most fed upon through 8 d. *Coptotermes formosanus* fed on 'Moneymaker' at a significantly greater ($P < 0.05$) level than all other cultivars. When ranked, the commercially important cultivars occurred along, and were dispersed throughout, the continuum of cultivar preferences shown in Table 1 and Fig. 1. However, it is important to note that five of the six cultivars most preferred by *C. formosanus* were considered commercially important in present day pecan production (Table 1). Termites in the untreated controls for this experiment suffered less than 10% mortality throughout the 8 d period. The mean weight difference for the untreated controls of all 56 cultivars was 0.003 g. The mean consumption values of all 56 cultivars through three replications over an 8 d period are presented in Table 1.

DISCUSSION

It was determined that *C. formosanus* foragers differentially preferred to feed on the wood of specific pecan cultivars. Of the 56 cultivars examined, 'Creek' and 'Barton', had only 2.71 % as much cellulose removed by termite feeding as did the commercially important cultivar 'Moneymaker'. The concept of acquired or selected traits through plant breeding programs that are performed by the scientists at the USDA Pecan Breeding and Genetic Program, Southern Plains Agricultural Research Center, would pertain to those cultivars with resistance or tolerance to termite feeding. It is apparent that they have successfully bred for traits such as yield, disease resistance, and tolerance to many insect groups. However, to this point in time, little or no attention has been given to termite feeding in the selection processes. Based on the results of this research, there are traits that could result in diminished termite feeding.

It is highly probable that breeding for traits that are resistant to termite feeding could be incorporated into the commercial cultivars through time. More work would need to be done to identify the specific characteristics

Table 1. Summary of the mean consumption of wood from 56 pecan cultivars by 250 Formosan termites in laboratory studies conducted over an 8 d period.

Rank	Cultivar	Mean Consumption (g)		Rank	Cultivar	Mean Consumption (g)		Rank	Cultivar	Mean Consumption	
1	Creek	0.017±0.004	a	20	Warren	0.067±0.020	abcde	39	Riverside	0.123±0.023	abcdef
2	Clark	0.019±0.009	a	21	Shawnee	0.068±0.024	abcde	40	Schley	0.126±0.010	abcdef
3	Wichita	0.028±0.011	ab*	22	Oconee	0.069±0.032	abcde*	41	Desirable	0.134±0.032	abcdef*
4	Navaho	0.029±0.007	ab	23	Forkert	0.069±0.009	abcde	42	Baker	0.138±0.067	abcdef
5	Hopi	0.029±0.015	ab	24	Apache	0.070±0.010	abcde	43	Moore	0.141±0.031	abcdef
6	Chickasaw	0.041±0.017	ab	25	Burkett	0.071±0.024	abcde	44	James	0.147±0.029	abcdef
7	Barton	0.045±0.020	abc	26	Caddo	0.075±0.021	abcde*	45	Woodside	0.166±0.026	bcdefg
8	Osage	0.045±0.013	abc*	27	Carter	0.075±0.004	abcde	46	Schaeffer	0.162±0.032	bcdefg
9	Kiowa	0.046±0.023	abc*	28	Mississippi	0.081±0.023	abcdef	47	Philema	0.167±0.071	bcdefg
10	Apache #5	0.051±0.022	abcd	29	San Felipe	0.096±0.011	abcdef	48	Alley	0.180±0.041	cdefg
11	Lucas	0.054±0.027	abcde	30	Nelson	0.096±0.009	abcdef	49	Dependable	0.192±0.027	defg
12	Pawnee	0.056±0.035	abcde*	31	Houma	0.098±0.021	abcdef	50	Tejas	0.192±0.055	efg
13	Walnut	0.056±0.029	abcde	32	Ramsey M.	0.103±0.009	abcdef	51	Mahan	0.193±0.019	efg*
14	Choctaw	0.058±0.008	abcd	33	Cherryle	0.107±0.006	abcdef	52	Giles	0.218±0.077	fgh*
15	Candy	0.059±0.032	abcde*	34	Mohawk	0.109±0.018	abcdef*	53	Brake	0.302±0.208	ghi*
16	Kanza	0.059±0.008	abcde*	35	Van Deman	0.112±0.020	abcdef	54	Cooper	0.358±0.257	hi
17	Woodroof	0.061±0.008	abcde	36	Sioux	0.117±0.051	abcdef*	55	Stuart	0.361±0.066	i*
18	Shoshoni	0.062±0.025	abcde*	37	Hughes	0.118±0.019	abcdef	56	Moneymaker	0.637±0.080	j*
19	Comanche	0.063±0.018	abcde	38	Waukeenah	0.121±0.019	abcdef				

*Indicates a commercially important cultivar based on the number of trees currently in production (Texas in 2009)

-Means followed by the same letter were not significantly different using ANOVA, and Tukey HSD (Honestly Significant Difference) (SPSS v. 16.0).

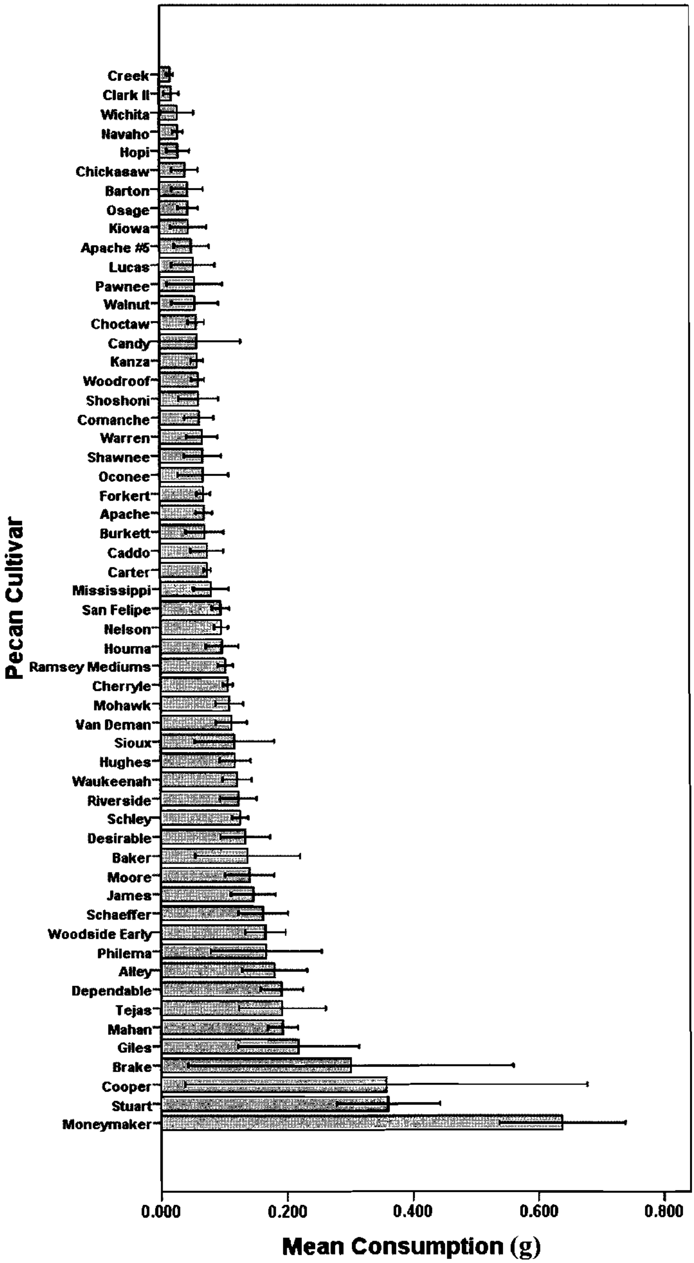

Fig. 1. Mean consumption of wood from 56 pecan cultivars by 250 Formosan termites in laboratory studies conducted over an 8 d period.

that would have commercial value in attempting to balance nut yields to survivability of selected cultivars. Because it takes considerable time to undergo the selection process, the results of this research would indicate that there are cultivars presently available that could be moved to production as replacement stock. It is inevitable that Formosan termites will continue to move into pecan production areas, where the trees will be found, fed upon and eventually killed.

In addition to loss of trees by Formosan termites feeding in commercial areas, pecans are a popular ornamental tree used in urban landscapes because of aesthetics and nut production. In these urban situations, when the pecan trees are attacked by Formosan termites, the aesthetic value is reduced and the risk of these trees falling on structures is increased, particularly during high wind situations. (Edwards & Mill 1986; Su & Tamashiro 1987; Su & Scheffrahn 1990). Therefore, if a less preferred pecan cultivar is used, even in urban landscapes, some degree of risk can be mitigated.

This research reveals the potential impact Formosan termites will have on the pecan agro-industry. For the commercial pecan grower, these results may offer some additional information regarding specific cultivars at risk, which should enhance the need for regular inspections for invading termites. However, research is needed before inclusion of the risk of *C. formosanus* infestation can be added to the 'decision rubric' with regards to the production of specific pecan cultivars.

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REFERENCES

Edwards, R. & A.E. Mill. 1986. Termites in buildings, their biology and control. Rentokil Limited, East Grinstead, U.K., pp. 261.

Glenn, G.J. & R.E. Gold. 2003. Evaluation of commercial termiticides and baiting systems for pest management of the Formosan subterranean termite, *Coptotermes formosanus* (Isoptera: Rhinotermitidae). Sociobiol. 41: 193-196.

Gold, R. E., H.N. Howell Jr., B.M. Pawson, M.S. Wright & J.C Lutz. 1996. Persistence and bioavailability of termiticides to subterranean termites (Isoptera: Rhinotermitidae) from five soil types and locations in Texas. Sociobiol. 28: 337-363.

Grace, J. K., C.H.M. Tome, T.G. Shelton, R.J. Oshiro & J.R. Yates III. 1996 Baiting studies and considerations with *Coptotermes formosanus* (Isoptera: Rhinotermitidae) control in Hawaii. Sociobiol. 28: 511-520.

La Fage, J. P. 1987. Practical considerations of the Formosan subterranean termite in Louisiana: a 30-year-old problem. pp. 37-42. *In*: Biology and control of the Formosan subterranean termite, M. Tamahiro and N. Y. Su (eds.) Research and Extension Series 083, College of Tropical Agriculture and Human Resources, Univ. of Hawaii, Honolulu.

Mao, L., G. Henderson, Y.Liu & R.A. Laine 2005. Formosan Subterranean Termite (Isopter: Rhinotermitidae) Soldiers Regulate Juvenile Hormone Levels and Caste Differentiation in Workers. Annals of the Entomological Society of America. 98: 340-345.

Mcquaid, J. 2009. Termite home wreckers. The Times-Picayune. http://www.nola.com/speced/homewrecker/day1shredsoua.html. June 15, 2009.

Morales-Ramos, J.A. & M.G. Rojas. 2001. Nutritional ecology of the Formosan subterranean termite (Isoptera: Rhinotermitidae): feeding response to commercial wood species. J. Econ. Entomol. 94: 516-523.

Osbrink, W.L.A., W.D. Woodson & A.R. Lax. 1999. Populations of Formosan subterranean termite, *Coptotermes formosanus* (Isoptera: Rhinotermitidae), established in living urban trees in New Orleans, Louisiana, U.S.A. *In*: Robinson, W.H., Rettich, F., and Rambo, G.W., eds. Proceedings of the 3rd International Conference on Urban Pests, Czech Republic: Graficke zavody Hronov, pp. 341-345.

SPSS for Windows. Rel. 16.0.1. 2009. Chicago: SPSS Inc.

Su, N.-Y. & M. Tamashiro. 1987. An overview of the Formosan subterranean termite (Isoptera:Rhinotermitidae) in the world, pp. 3-14. *In*: Biology and Control of the Formosan subterranean termite M. Tamashiro and N.-Y. Su, eds., Research and Extension Series 083. College of Tropical Agriculture and Human Resources, Univ. of Hawaii, Honolulu.

Su, N.-Y.,& R.H. Scheffrahn. 1990. Update of the Formosan subterranean termite. Proc. Nat'l. Conference on Urban Entomology. Clemson, S.C., pp. 41-45.

Thompson, T. E. & E. F. Young Jr. 1985. Pecan cultivars-past and present. Pecan Growers Assoc. College Station, Tex. 265pp.