Reprinted from Environmental Entomology 15(4): 951-953. # 109

Relationship of Phoretic Mites (Acari: Tarsonemidae) to the Bluestaining Fungus, *Ceratocystis minor*, in Trees Infested by Southern Pine Beetle (Coleoptera: Scolytidae)

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Environ. Entomol. 15: 951–953 (1986)

ABSTRACT Amount of bluestain caused by *Ceratocystis minor* (Hedgcock) Hunt in trees infested with the southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, was measured in three Texas and Louisiana forests. It was significantly correlated with number of *Tarsonemus krantzi* Smiley & Moser, a mite phoretic on SPB. Significantly less bluestain and significantly fewer mites were found in certain Texas infestations where SPB outbreak was most severe.

KEY WORDS *Dendroctonus frontalis, Tarsonemus krantzi, Tarsonemus ips, Ceratocystis minor*

BLUESTAINING FUNGUS, *Ceratocystis minor* (Hedgcock) Hunt, is usually introduced into trees by attacking southern pine beetles (SPB), *Dendroctonus frontalis* Zimmermann. SPB also carries a number of mites including two species of tarsonemids, *Tarsonemus krantzi* Smiley & Moser and *T. ips* Lindquist (Moser & Roton 1971, Kinn 1976). These phoretic mites have structures called sporothecae (Moser 1985) that carry ascospores of *C. minor*. Bridges & Moser (1983) postulated a role for phoretic mites in the transmission of *C. minor*. They showed that SPB carrying tarsonemid mites carry *C. minor* more often than mite-free beetles. However, that study did not compare mite population levels with the occurrence of bluestain in SPB infestations.

We hypothesized that if mites vector the bluestaining fungus, the amount of *C. minor* in SPB-infested trees would vary with mite population fluctuations. To test this hypothesis, we measured phoretic mite population densities and fungus occurrence in SPB-infested trees to determine the relationship of mites and bluestain.

Materials and Methods

From June to September 1984, bluestain was measured in SPB infestations in the Sam Houston and Sabine National Forests in Texas and in the Kisatchie National Forest in Louisiana. Sapwood stained by *C. minor* was measured in 57 SPB-infested trees. Measurements of bluestain were made at heights of 1.5, 3.5, and 6.5 m in each tree. Four bark samples (100 cm^2) were removed at each height, and the wood bluestained by *C. minor* was traced onto a piece of mylar. The area of bluestained wood was measured on the mylar (Bridges et al. 1985).

Beetles were examined from each tree to determine the number of *T. krantzi* and *T. ips* they carried. Bark was removed at 3.5 m, taken to the laboratory, and placed in rearing containers. Thirty emerging beetles were collected from each tree and stored in vials of alcohol. Beetles and alcohol were examined to determine the number of *T. krantzi* and *T. ips* in each sample. Mites also were examined microscopically to determine the number of *C. minor* ascospores they carried (Moser 1985).

To analyze the data, measurements of bluestain were pooled for each tree. Data were analyzed using Kruskal–Wallis tests (Conover 1980) to determine differences among sample locations in the amount of bluestain, number of mites, and the proportion of mites that carried spores. Spearman's rank correlation procedure (Conover 1980) was used to determine the degree of correlation between bluestained area and number of mites.

Results and Discussion

SPB-infested trees in the Sam Houston National Forest contained only ca. 33% as much bluestain as trees from the Sabine or Kisatchie National Forests. Significantly more of the samples from the Sam Houston National Forest were bluestain-free compared with samples from the other two areas (Table 1).

There were significantly fewer *T. krantzi* on SPB collected from the Sam Houston National Forest than on those from the other two areas, and significantly fewer *T. ips* on SPB from the Sam Houston and Kisatchie National Forests than on those from the Sabine National Forest (Table 1). There was a significant correlation between the area stained by *C. minor* and the number of *T. krantzi* per beetle ($r = 0.70$; $P < 0.01$; $n = 57$), but no significant correlation with numbers of *T.*

Table 1. Differences in the amount of bluestain and number of phoretic mites from SPB-infested trees from the Sam Houston, Sabine, and Kisatchie National Forests

National Forest	No. of trees	$\bar{x}$ area of sample with bluestain ± SD (cm²)[a]	$\bar{x}$ no. of bluestain-free samples per tree ± SD[b]	$\bar{x}$ no. of mites per 30 beetles ± SD	
				T. krantzi	*T. ips*
Sam Houston	34	3.9 ± 7.0a	6.6 ± 4.4a	8.7 ± 27.2a	7.5 ± 7.4a
Sabine	12	13.9 ± 8.3b	0.7 ± 2.0b	33.2 ± 16.4b	22.0 ± 11.9b
Kisatchie	11	11.3 ± 7.0b	0.3 ± 0.6b	30.0 ± 37.5b	6.3 ± 12.0a

Means within a column not followed by the same letter are significantly different ($P < 0.05$; Kruskal–Wallis test).
[a] Area per 100-cm² sample.
[b] Total number of samples per tree was 12.

ips ($r = 0.21$; $P > 0.05$; $n = 57$), although this mite carried fungal spores about as frequently as *T. krantzi* (Table 2). There was generally no significant difference among forests in the proportion of mites that carried spores, but a smaller proportion of *T. ips* from the Sam Houston National Forest carried spores than *T. ips* from the Kisatchie National Forest (Table 2).

Five of 34 trees sampled in the Sam Houston National Forest had no bluestain in any of the 12 samples examined per tree. Four of these bluestain-free trees had no *T. krantzi* on the SPB examined. However, *T. ips* were found on SPB in all but one of the bluestain-free trees, suggesting that *T. ips* may have alternate food sources. *C. minor* is thought to be the primary food for *T. krantzi*, although trophic relationships have not been studied. It should be noted here that *T. ips* is phoretic on a large number of coniferous bark beetles worldwide (Lindquist 1969), and *C. minor* is absent for much of its range. The geographic distribution of *T. krantzi*, however, seems to be restricted to its primary phoretic host, SPB (Smiley & Moser 1974, Moser et al. 1974). *C. minor* is found throughout the range of SPB.

SPB population levels were higher in the Sam Houston National Forest than in the other two areas. This fact can be shown by comparing the volume of timber cut for SPB control.[1] During June through September 1984, 2.4 m³/ha of timber of susceptible host type was salvaged from the Sam Houston National Forest. During the same period, only 0.6 and 0.1 m³/ha of timber of susceptible host type were cut for SPB control in the Sabine and Kisatchie National Forests, respectively. In addition to salvaged timber, 553 multiple tree infestations were cut but not salvaged in the Sam Houston National Forest for SPB control. In the Sabine, 13 SPB infestations were cut but not salvaged. There were no cut-and-leave treatments in the Kisatchie National Forest.

Our results show that the levels of bluestain and the occurrence of phoretic *T. krantzi* associated with SPB infestations varied among locations and that the lowest incidences of mites and bluestain were associated with outbreak populations of SPB. These and other observations (Texas Forest Service 1978, Bridges 1985, Bridges et al. 1985) suggest that low levels of bluestain are characteristic of outbreak populations of SPB. Data from this study are the first to suggest that a low incidence of phoretic mites may also be a feature of SPB epidemics.

Although we found a significant relationship between the occurrence of phoretic *T. krantzi* and bluestain in SPB populations, we cannot establish cause and effect relationships. Tarsonemid mites feed on *C. minor* in SPB-infested trees. Thus, changes in the abundance of *C. minor* could cause changes in tarsonemid populations. We have suggested (Bridges & Moser 1983) that tarsonemid mites vector *C. minor* by carrying spores in sporothecae (Moser 1985). Therefore, changes in mite populations could cause changes in bluestain abundance. Because of the interrelationships between mites, bluestain, and SPB infestation levels, knowledge of phoretic mites could be important to understanding the population dynamics and epidemiology of SPB.

[1] Data for the Sam Houston and Sabine National Forests were obtained from Forest Pest Management, USDA Forest Service, 2500 Shreveport Hwy., Pineville, LA 71360. Data for the Kisatchie National Forest were provided by the Supervisor's Office, 2500 Shreveport Hwy., Pineville, LA 71360. Volume estimates for this forest included only data from the Catahoula and Winn Ranger Districts where samples were taken.

Table 2. Percentage of phoretic mites with ascospores from SPB-infested trees from the Sam Houston, Sabine, and Kisatchie National Forests

National Forest	$\bar{x}$ % with spores ± SD	
	T. krantzi	*T. ips*
Sam Houston	8.3 ± 16.6a	4.9 ± 18.2a
Sabine	9.7 ± 16.9a	6.5 ± 14.3ab
Kisatchie	20.2 ± 23.9a	20.8 ± 31.8b

Means within a column not followed by the same letter are significantly different ($P < 0.05$; Kruskal–Wallis test).

References Cited

Bridges, J. R. 1985. Relationship of symbiotic fungi to southern pine beetle population trends. *In* S. J. Branham & R. C. Thatcher [eds.], Integrated pest management research symposium: the proceedings. USDA For. Ser., South. For. Exp. Stn. Gen. Tech. Rep. SO-56: 127–135.

Bridges, J. R. & J. C. Moser. 1983. Role of two phoretic mites in transmission of bluestain fungus, *Ceratocystis minor*. Ecol. Entomol. 8: 9–12.

Bridges, J. R., W. A. Nettleton & M. D. Connor. 1985. Southern pine beetle (Coleoptera: Scolytidae) infestations without the bluestain fungus, *Ceratocystis minor*. J. Econ. Entomol. 78: 325–327.

Conover, W. J. 1980. Practical nonparametric statistics, 2nd ed. Wiley, New York.

Kinn, D. N. 1976. Key to mites commonly associated with the southern pine beetle. USDA For. Ser., South. For. Exp. Stn. Res. Note SO-214.

Lindquist, E. E. 1969. New species of *Tarsonemus* (Acarina: Tarsonemidae) associated with bark beetles. Can. Entomol. 101: 1291–1314.

Moser, J. C. 1985. Use of sporothecae by phoretic *Tarsonemus* mites to transport ascospores of coniferous bluestain fungi. Trans. Br. Mycol. Soc. 84: 750–753.

Moser, J. C. & L. M. Roton. 1971. Mites associated with southern pine bark beetles in Allen Parish, Louisiana. Can. Entomol. 103: 1775–1798.

Moser, J. C., R. C. Wilkinson & E. W. Clark. 1974. Mites associated with *Dendroctonus frontalis* Zimmermann (Scolytidae: Coleoptera) in Central America and Mexico. Turrialba 24: 379–381.

Smiley, R. L. & J. C. Moser. 1974. New tarsonemids associated with bark beetles (Acarina: Tarsonemidae). Ann. Entomol. Soc. Am. 67: 639–665.

Texas Forest Service. 1978. Texas forest pest activity 1976–1977 and forest pest control section biennial report. Tex. For. Serv. Publ. 117.

Received for publication 16 December 1985; accepted 19 May 1986.