TRANS-VERBENOL, TURPENTINE, AND ETHANOL AS TRAP BAITS FOR THE BLACK TURPENTINE BEETLE, *DENDROCTONUS TEREBRANS*,[1] AND OTHER FOREST COLEOPTERA IN NORTH FLORIDA[2]

C. W. Fatzinger,[3] B. D. Siegfried,[4]
R. C. Wilkinson,[5] and J. L. Nation [5]
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ABSTRACT

Trans-verbenol, ethanol, and gum turpentine were evaluated alone and in combinations as trap baits for the black turpentine beetle (BTB), *Dendroctonus terebrans* (Olivier). Traps without turpentine generally caught fewer BTB, pales weevils, *Hylobius pales* (Herbst), pitch-eating weevils, *Pachylobius picivorus* (Germar); southern pine sawyers, *Monochamus titillator* (F.), and Carolina pine sawyers, *M. carolinensis* (Olivier). *Trans*-verbenol alone was ineffective as a trap bait, but sometimes increased catches of BTB 1.2 to 1.5 times when used in combination with turpentine or a mixture of turpentine and ethanol. The addition of ethanol to the turpentine bait sometimes doubled catches of BTB and increased captures of pales weevils 3.7 to 5.1 times. The overall effect of mixing ethanol with turpentine bait while releasing *trans*-verbenol from the same trap versus the use of turpentine alone was a 2.4-fold increase in the response of female BTB. Traps captured about equal numbers of male and female BTB, pales weevils, pitch-eating weevils, and southern pine sawyers, but captured 2.8 times more female than male Carolina pine sawyers.

Key Words: Black turpentine beetle, *Dendroctonus terebrans*, insect attractants, *trans*-verbenol, turpentine, ethanol, oleoresin, monoterpenes, pheromones.

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INTRODUCTION

Southern pines stressed by disturbances such as logging, prolonged drought, lightning, fire, chemicals, or severe wounding are preferred hosts of the black turpentine beetle (BTB), *Dendroctonus terebrans* (Olivier). Adults are attracted to the fresh oleoresin of pines (Smith 1963; Ciesla and Franklin 1965; Hughes 1975) and prefer to breed in the inner bark of freshly cut stumps or the bases and roots of weakened or dying trees (Smith 1957; Smith and Kowal 1968; Merkel 1981).

Large numbers of BTB have been captured in traps baited with turpentine freshly distilled from the oleoresin of slash, *Pinus elliottii* Englem. var. *elliottii*, and longleaf, *P. palustris* Mill., pines (Clements and Williams 1981). Similar traps baited with turpentine captured several other forest Coleoptera including Cerambycidae (the Carolina pine sawyer, *Monochamus carolinensis* (Olivier), the southern pine sawyer, *M. titillator* (F.), and *Prionus* spp.); Curculionidae (the pales

[1] Coleoptera: Scolytidae.

[2] Mention of proprietary names is for identification purposes only and does not constitute endorsement by the USDA.

[3] Southeastern Forest Experiment Station, P.O. Box 70, Olustee, FL 32072.

[4] Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611. Present address: Pesticide Research Laboratory, Pennsylvania State University, University Park, PA 16802.

[5] Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611.

weevil, *Hylobius pales* (Herbst), the pitch-eating weevil, *Pachylobius picivorus* (Germar), and the deodar weevil, *Pissodes nemorensis* Germar); Platypodidae (the southern pine ambrosia beetle, *Platypus flavicornis* (F.)); Scolytidae (southern pine engraver beetles, *Ips* spp., and ambrosia beetles, *Xyleborus* spp.); and Trogositidae (*Temnochila virescens* (F.) (Fatzinger 1985). Billings (1985) showed that the rapid release of pine turpentine from traps baited with bark beetle attractants increases the response of the southern pine beetle, *D. frontalis* Zimm., *Thanasimus dubius* (F.), the southern pine sawyer, and *T. virescens.*

Attractants for most scolytids are complexes of more than one compound (Borden 1982). Ethanol alone or in combination with monoterpenes can act as an attractant for a number of scolytids (Moeck 1970; Borden et al. 1980). For example, Cade et al. (1970) found that ethanol, produced by decomposing logs of western hemlock, *Tsuga heterophylla* [Raf.] Sarg., served as a primary attractant for the ambrosia beetle, *Gnathotrichus sulcatus* LeConte. Rudinsky (1966) found that almost 4 times as many Douglas-fir beetles, *Dendroctonus pseudotsugae* Hopkins, were attracted to Douglas-fir, *Pseudotsuga menziesii* [Mirb.] Franco, oleoresin diluted with ethanol than to oleoresin exuded from the ends of freshly cut logs. Trap captures of the BTB also were increased by 59% when a turpentine bait was diluted with ethanol (Fatzinger 1985).

Trans-verbenol functions as a component of aggregation pheromone complexes for several species of bark beetles, either as a synergist with another compound or as the main constituent (Bedard et al. 1980; Wood 1982). Aggregation pheromones are known to be involved in the attack behavior of BTB. Smith (1958) found that wounded pines newly infested by BTB were 12 times more prone to additional beetle attacks than wounded pines that had not been infested. Godbee and Franklin (1976) also suggested that unidentified secondary attractants were produced by virgin adult BTB artificially introduced into log bolts. Recently, Payne et al. (1987) have shown that BTB adults show sex-specific responses to the aggregation pheromones frontalin and *endo*-brevicomin when these behavioral chemicals were released in the presence of pine turpentine. Adults and larvae of BTB were shown in laboratory tests to be capable of metabolizing alpha-pinene to *trans*-verbenol (Hughes 1975), but this pheromone has not been evaluated as a possible attractant for this species.

In this field study we evaluated *trans*-verbenol separately and in combination with turpentine and ethanol as a trap bait for capturing adult BTB. The baits also were evaluated for efficacy in capturing other forest Coleoptera attracted to the same traps.

METHODS AND MATERIALS

The study was conducted in mixed stands of slash and longleaf pines in Baker County near Olustee, FL. Freshly distilled gum turpentine of slash and longleaf pines,[6] 95% ethanol, and a mixture of turpentine and ethanol (1:1, v/v) were released from 500 ml wick-type dispensers attached to the tops of traps consisting of black bounce columns (23 cm diameter by 1.2 m long) supported vertically in the center of water-filled plastic wading pools (1.2 m diameter by 25 cm deep) (Fatzinger 1985). These dispensers release the turpentine and ethanol mixture at a

[6] Obtained from Shelton Naval Stores Processing Company, Valdosta, GA.

rate of ca. 57 mg/hr at daily temperatures of 15°C. *Trans*-verbenol[7] (50 µl) was dispensed from a serum bottle stopper[8] suspended on a wire attached to the outside of the wick-type dispenser. The baits were shielded from rain and direct sunlight by a small sheet-metal roof (15 × 15 cm) attached over the top of each dispenser.

The relative attractiveness of different baits was compared in tests of 3 or 4 replicate traps per bait (treatment) arranged in completely randomized Latin square designs (Cochran and Cox 1957). Traps within a Latin square were located 30 m apart in straight lines and at least 10 m from the nearest trees. Duplicate Latin squares were located from 100 to 150 m apart. The numbers of beetles captured per trap were recorded and the baits were rotated to a new randomized position within the Latin squares at intervals of 3 to 4 days. Traps represented columns of the Latin squares and days represented rows (Billings et al. 1976). BTB were sexed by morphological differences of the 7th abdominal tergite (Godbee and Franklin 1978). The Carolina and southern pine sawyers were distinguished by morphological differences between the apices of elytra (Knull 1946). Catch data were tested by analysis of variance and significantly different means ($P \leq 0.05$) were identified by Duncan's (1955) multiple range test.

Experiment I was repeated twice, once during August and once during September 1983. Only 3 baits were used: *trans*-verbenol, turpentine, or *trans*-verbenol plus turpentine. The baits were represented twice in each of 2 Latin squares of 6 traps each for a total of 8 replicates per bait (2 Latin squares × 2 baits/square × 2 replicate experiments). BTB were collected from traps every 4 days for a total of 24 collections per bait. The *trans*-verbenol baits were replaced and the turpentine baits were replenished daily. Sex ratios (males:females) of BTB responding to the baits were subjected to chi-square analysis to estimate differences from a 1:1 ratio.

Two additional experiments were conducted during 1984 to include ethanol alone and in combination with turpentine and *trans*-verbenol. Each Latin square included 7 traps baited with the 3 attractants and 4 different combinations of them and was replicated 3 times. The turpentine and ethanol baits were replenished at intervals of 3 to 4 days. Experiment II was repeated 3 times from July to September. The baits were represented once in each of 3 Latin squares of 7 traps each for a total of 9 replicates per bait (3 Latin squares × 3 replicate experiments). A total of 63 trap collections were made per bait and the *trans*-verbenol baits were replaced at intervals of 3 to 4 days. Experiment III was conducted from September to November and was identical to experiment II except that the *trans*-verbenol baits were replaced daily ca. 2 hr prior to peak BTB flight activity (between 1600 - 1700 hr, Fatzinger 1985). Experiment III was conducted only once for a total of 3 replicates per bait and 21 trap collections per bait.

RESULTS

Ten species representing 4 families (Cerambycidae, Curculionidae, Platypodidae, and Scolytidae) of forest Coleoptera were captured by the traps including 2

[7] Obtained from Stratford Chemical Developments Ltd., Vancouver, B.C. and SCM Organics, Jacksonville, FL.

[8] Red rubber stoppers with hollow plugs for serum bottles, size 11.5, No. 03-215-5, Fisher Scientific Co., Orlando, FL.

cerambycids, *Arhopalus rusticus obsoletus* (Rand.) and *Xylotrechus saggittatus* (Germ.), that had not been caught during previous studies. Pales weevils were captured in larger numbers and more frequently than any other species. In addition to the species listed in Tables 1 - 3, trap captures also included 66 *Prionus* spp., 175 *T. virescens,* and 132 *P. nemorensis.*

Table 1. Mean numbers of *Dendroctonus terebrans* captured per trap over intervals of 3 to 4 days with *trans*-verbenol released at a rate of 50 µl/day from August to September 1983 (Exp. I) and September to November 1984 (Exp. III) and with *trans*-verbenol released at 50 µl every 3 to 4 days from July to September 1984 (Exp. II) near Olustee, FL.

Trap bait‡	Avg. no./trap* Exp. I† Male	Exp. I† Female	Exp. II† Male	Exp. II† Female	Exp. III† Male	Exp. III† Female
TEV	NT§	NT	8.5a	7.9a	8.6a	8.2a
TE	NT	NT	6.9b	7.9a	6.8ab	6.0b
TV	7.4a	7.0a	3.8c	3.2b	5.2bc	3.9b
T	5.8a	4.7b	3.6c	3.4b	4.0c	4.0b
E	NT	NT	0.1d	0.1c	0.1d	0.0c
V	0.1b	0.2c	0.2d	0.2c	0.0d	0.1c
EV	NT	NT	0.1d	0.1c	0.1d	0.1c

* No. collections per trap: Experiment I = 24, Experiment II = 63, Experiment III = 21.

† Means within a column followed by the same letter are not significantly different at $P = 0.05$, Duncan's (1955) multiple range test.

‡ T = turpentine, E = ethanol, V = *trans*-verbenol.

§ NT = not tested.

Experiment I (Turpentine, Trans-verbenol)

Only a few (n = 6) BTB adults were attracted to *trans*-verbenol alone, whereas the combination of turpentine and *trans*-verbenol attracted 347 beetles. This latter figure represents a 38% increase in total captures over traps baited with turpentine alone (n = 251). Most of this was due to a significant ($P \leq 0.05$) increase in female responses (+49%) to this combination (Table 1). Sex ratios of BTB attracted to turpentine (chi-square = 0.14) or turpentine plus *trans*-verbenol (chi-square = 2.07) were not significantly different from a 1:1 ratio.

Experiments II and III (Turpentine, Trans-verbenol, Ethanol)

Trap baits without turpentine generally attracted fewer BTB, weevils, and cerambycids than baits with turpentine alone or in combination (Tables 1 - 3). Responses of weevils and cerambycids to *trans*-verbenol plus turpentine were not significantly greater than to turpentine alone. *Trans*-verbenol, however, had the effect of increasing the response by BTB females when released with turpentine (Experiment I) and when released with turpentine and ethanol (Experiment III).

Black Turpentine Beetle — Traps baited with turpentine plus ethanol mixture captured ca. 1.5 - 2.0 times as many BTB as did traps baited with turpentine only, and captured significantly more BTB than traps baited with turpentine plus *trans*-verbenol during Experiment II. During Experiment III, the turpentine and ethanol

Table 2. Mean numbers of pine reproduction weevils captured per trap from 12 July to 24 September 1984 (Exp. II) and 28 September to 9 November 1984 (Exp. III) near Olustee, FL.

Trap bait‡	Avg. no./trap*			
	Hylobius pales†		*Pachylobius picivorus*†	
	Male	Female	Male	Female
		Exp. II		
TE	13.22a	11.32a	2.27a	1.59a
TEV	13.03a	11.22a	2.05ab	1.56a
TV	3.48b	3.19b	1.87ab	1.48a
T	2.59b	3.08b	1.56b	1.62a
E	0.52c	0.50c	0.22c	0.42b
V	0.23c	0.34c	0.09c	0.09b
EV	0.43c	0.44c	0.27c	0.10b
		Exp. III		
TE	41.57a	41.48a	0.57a	0.62a
TEV	26.67b	27.52b	0.52ab	0.38abc
TV	12.35c	15.35c	0.50ab	0.45ab
T	12.60c	13.60c	0.80a	0.55a
E	1.33c	1.86d	0.10bc	0.05c
V	0.76c	0.76d	0.05c	0.05c
EV	1.14c	0.71d	0.05c	0.10bc

* No. collections per trap: Experiment II = 63, Experiment III = 21. *Trans*-verbenol was released from traps at a rate of 50 µl every 3 to 4 days during Exp. II and at a rate of 50 µl/day during Exp. III.

† Means within a column followed by the same letter are not significantly different at the $P = 0.05$ level, Duncan's (1955) multiple range test.

‡ T = turpentine, E = ethanol, V = *trans*-verbenol.

mixture attracted significantly more male BTB than did turpentine alone, but there were no significant differences between captures of males or females by the turpentine and ethanol mixture and by turpentine plus *trans*-verbenol baits. *Trans*-verbenol increased captures of BTB only when it was released from traps baited with the turpentine and ethanol mixture, and this bait generally captured more BTB than the others. Traps baited with all 3 attractants captured more male BTB when *trans*-verbenol was released at a rate of 50 µl every 3 to 4 days (Experiment II) and more female BTB when released at 50 µl/day (Experiment III), than traps with the turpentine and ethanol mixture alone. The sex ratios of BTB captured by traps baited with the 3 attractants were about equal, i.e., 1.08:1 during Experiment II and 1.05:1 during Experiment III.

Pine Reproduction Weevils — Traps captured 2.4 times as many pine reproduction weevils as BTB and 7.7 times more pales than pitch-eating weevils. Ethanol had a significant synergistic effect (3.7 - 5.1-fold increase) with turpentine as a bait for both male and female pales weevils, but increased captures only of male pitch-eating weevils (Table 2). *Trans*-verbenol had little positive effect on captures of either the pales or pitch-eating weevils. In fact, ca. ⅓ fewer pales weevils were captured when *trans*-verbenol was released at a rate of 50 µl per day with the

Table 3. Mean numbers of cerambycids captured per trap at intervals of 3 to 4 days from 12 July to 24 September 1984 (Exp. II) and 28 September to 9 November 1984 (Exp. III) near Olustee, FL.

	Avg. no./trap*					
Trap bait‡	*Monochamus titillator*† Male	*Monochamus titillator*† Female	*Monochamus carolinensis*† Male	*Monochamus carolinensis*† Female	*Xylotrechus sagittatus*	*Arhopalus rusticus obsoletus*
			Exp. II			
TEV	0.86a	0.82a	0.51ab	1.33ab	1.82a	1.81a
TE	0.63ab	0.79a	0.60a	1.60a	1.82a	1.97a
TV	0.35bc	0.41b	0.27abc	1.02abc	0.51b	0.32b
T	0.41b	0.48b	0.33abc	0.76bcd	0.48b	0.20b
E	0.05d	0.05c	0.24bc	0.82bcd	0.10bc	0.02b
V	0.02d	0.03c	0.12c	0.39d	0.05c	0.03b
EV	0.08cd	0.02c	0.11c	0.48cd	0.03c	0.25b
			Exp. III			
TEV	0.62bc	1.14ab	0.33ab	1.00ab	1.14ab	0.76a
TE	1.38a	1.52a	0.67a	1.38a	1.33a	1.00ab
TV	0.85ab	0.65bc	0.20b	0.60ab	0.70abc	0.05b
T	0.70abc	0.60bc	0.35ab	0.60ab	0.70abc	0.00b
E	0.00c	0.05c	0.05b	0.24b	0.10bc	0.00b
V	0.05c	0.00c	0.10b	0.14b	0.00c	0.10b
EV	0.00c	0.14c	0.05b	0.28b	0.05c	0.00b

* No. collections per trap: Experiment II = 63, Experiment III = 21. *Trans*-verbenol was released from traps at a rate of 50 μl every 3 to 4 days during Exp. II and at a rate of 50 μl/day during Exp. III.

† Means within a column folowed by the same letter are not significantly different at P = 0.05, Duncan's (1955) multiple range test.

‡ T = turpentine, E = ethanol, V = *trans*-verbenol.

turpentine and ethanol mixture (Table 2, experiment III). Traps captured slightly more male than female pales and pitch-eating weevils, with sex ratios for total captures of 1:0.95 and 1:0.82, respectively.

Cerambycids — These beetles responded mostly to baits containing turpentine, but effects of adding *trans*-verbenol or ethanol were either lacking or inconsistent (Table 3). About 1.4 times as many Carolina pine sawyers as southern pine sawyers were captured during this study, but baits that included turpentine attracted nearly equal numbers of both species. A larger proportion of the total numbers of Carolina pine sawyers were attracted to the ethanol and *trans*-verbenol baits (23%) than were southern pine sawyers (4%). Most of the sawyers, however, were captured by traps baited with the turpentine and ethanol mixture (54% of the total capture) and about 30% of them were captured by turpentine alone. Traps captured about equal numbers of male and female southern pine sawyers (sex ratio = 1:0.90), but 73.8% of the Carolina pine sawyers were females (sex ratio = 1:2.82). *Xyleborus saggittatus* and *A. rusticus obsoletus* consistently responded in greatest numbers to baits containing turpentine and ethanol (Table 3). This consistency probably reflects a biological role of ethanol in host selection by these species.

DISCUSSION

Host-produced kairomones present in turpentine distilled from the oleoresin of slash and longleaf pines apparently can serve as primary attractants for the BTB and other forest Coleoptera, but these kairomones do not appear to be the only semiochemicals involved in the host selection process. The involvement of other semiochemicals were implicated by Smith (1958) and Godbee and Franklin (1976). Payne et al. (1987) found evidence that the pheromones frontalin and *endo*-brevicomin were attractive to BTB when released simultaneously with turpentine and suggested the possibility of a pheromonal system of intraspecific olfactory communication for the BTB. They found that both sexes of BTB produced and released *trans*-verbenol and myrtenol in addition to *exo*-brevicomin and traces of *endo*-brevicomin by males, and frontalin by females.

The effect of *trans*-verbenol as a primary or secondary attractant, or as a synergist for attractants, for BTB remains speculative (Table 1). It was ineffective as a trap bait when used alone, but sometimes increased catches 1.2 to 1.5 times when used in combination with turpentine or a mixture of turpentine and ethanol. In comparison, the addition of ethanol to the turpentine bait sometimes doubled trap catches. The overall effectiveness of mixing ethanol with turpentine bait and releasing *trans*-verbenol from the same trap compared with turpentine alone was to increase captures of female BTB by a factor of ca. 2.2. Further studies of the role of *trans*-verbenol should take into account its release rate as well as the simultaneous release rates of other behavioral chemicals, as suggested by Bedard et al. (1980) in relation to *D. brevicomis.*

Our findings that ethanol is synergistic with turpentine as a bait for reproduction weevils agrees with research in Sweden, where Tilles et al. (1984) found that ethanol is synergistic in combination with conifer host volatiles as an attractant for the large pine weevil, *H. abietis* (L.). They speculated that increased quantities of ethanol released from fermenting resinous host material may signal that such material is suitable for breeding.

The oleoresin of slash and longleaf pines probably contains primary attractants for *Monochamus* spp., which also may be enhanced by ethanol in decomposing trees. Billings and Cameron (1984) found that the southern pine sawyer responded in greatest numbers to traps baited with a mixture of pheromones (ipsenol, ipsdienol, and *cis*-verbenol) attractive to southern *Ips* spp., but that the sawyer was not attracted either to loblolly pine, *P. taeda* L., turpentine or a mixture of frontalin, *trans*-verbenol, and loblolly pine turpentine. The addition of turpentine to traps baited with *Ips* attractants resulted in greater catches of sawyers than when turpentine or the *Ips* attractants were used alone (Billings 1985). Our results also indicated a lack of responsiveness by this sawyer to *trans*-verbenol, but it was found to be highly responsive to turpentine distilled from slash and longleaf pines. The difference in the responses of the southern pine sawyer to the turpentines of loblolly and slash or longleaf pines could have resulted from differences in their chemical constituents or from differences in the release rates of turpentine from traps.

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