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(*S*)-(+)-IPSDIENOL: INTERSPECIFIC INHIBITION OF *Ips latidens* (LECONTE) BY *Ips pini* (SAY) (COLEOPTERA: SCOLYTIDAE)

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Abstract—In south-central British Columbia, the attraction of *Ips latidens* (LeConte) to its pheromone, ipsenol, was inhibited by (*S*)-(+)-ipsdienol, a pheromone for *I. pini* (Say). (*R*)-(−)-lpsdienol had no effect on *I. latidens*. (*S*)-(+)-lpsdienol probably plays a role in interspecific communication between the two species, facilitating reductions in interspecific competition for breeding material and/or interspecific mating interference.

Key Words—Coleoptera, Scolytidae, *Ips latidens*, *Ips pini*, interspecific communication, synomone, pheromone, ipsenol, ipsdienol, chirality, enantiospecificity.

INTRODUCTION

Ecological and reproductive isolation among bark beetles can be facilitated by the use of pheromones (Wood, 1970; Lanier and Burkholder, 1974; West-Eberhard, 1984; Kohnle et al., 1986, 1988; Miller, 1991). Beetles are generally attracted to sources of pheromones produced by conspecifics while avoiding sources of pheromones produced by individuals of other species (Wood, 1970; Birch, 1978, 1984; Borden, 1982). In western North America for example, interspecific inhibition of responses to pheromones occurs between various sympatric species such as *Ips paraconfusus* Lanier and *I. pini* (Say) (Birch and Wood, 1975; Birch and Light 1977; Birch et al., 1977, 1980; Birch, 1978;

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Light and Birch, 1977) and *I. paraconfusus* and *Dendroctonus brevicomis* LeConte (Byers and Wood, 1980, 1981).

Ips pini and *I. latidens* (LeConte) are broadly sympatric in western North America and breed in large single-species aggregations, primarily in the phloem tissue of lodgepole pine (Bright, 1976; Furniss and Carolin, 1980; Wood, 1982). Both species use pheromones. In south-central British Columbia, *I. pini* produce ipsdienol with a mean chiral ratio of 66:34 (*S*)-(+):(*R*)-(−) (Miller et al., 1989). Both sexes are attracted to sources of ipsdienol with chiralities ranging from 30:70 to 80:20 (*S*)-(+):(*R*)-(−) (Miller, 1991). In the same region, male *I. latidens* produce ipsenol and both sexes respond to ipsenol regardless of chirality, although there is a slight preference for the (*S*)-(−) enantiomer (Miller et al., 1991).

Ipsenol inhibits the attraction of *I. pini* to infested material in Idaho (Furniss and Livingston, 1979) and California (Birch and Light, 1977). In south-central British Columbia, ipsenol inhibits the attraction of *I. pini* to ipsdienol-baited funnel traps (Borden et al., 1992). However, the effect of ipsdienol, produced by *I. pini*, on *I. latidens* has not been determined. We hypothesized that one or both enantiomers of ipsdienol inhibit the attraction of *I. latidens* to sources of ipsenol.

METHODS AND MATERIALS

Racemic ipsenol and racemic ipsdienol (chemical purities, 98% and > 95%, respectively) were obtained from Bedoukian Research Inc. (Danbury, Connecticut) and Borregaard, A.S. (Sarpsborg, Norway), respectively. E.K. Czyzewska (Department of Chemistry, Simon Fraser University, Burnaby, British Columbia) supplied chiral ipsdienols (optical purities, 98% (*S*)-(+) and 98% (*R*)-(−), respectively, chemical purities, > 98%).

Each lure consisted of 10 Microcap disposable pipettes (2 μl) (Drummond Scientific Co., Broomall, Pennsylvania), each sealed at one end and filled with either racemic ipsenol, racemic ipsdienol, or one of the chiral ipsdienols, and placed in a polyethylene, microcentrifuge tube (1.8 ml) (Evergreen Scientific, Los Angeles, California). The release rates of ipsenol and ipsdienol from such lures were both approximately 100 μg/day at 24°C (determined by weight loss).

In all experiments, replicates of four eight-unit, multiple-funnel traps (Lindgren, 1983) (Phero Tech Inc., Delta, British Columbia) were set in grids of 2 × 2 in stands of lodgepole pine near Princeton, British Columbia. Replicate grids were placed at least 100 m apart, and traps were spaced 10–15 m apart within each replicate. Each trap was suspended such that the top of each trap was approximately 1.3–1.5 m above ground level. No trap was within 2 m of

any tree. For each experiment, insects were collected only at the termination of the experiment.

Experiment 1 tested the effect of various chiralities of ipsdienol on the attraction of *I. latidens* to ipsenol. Ten replicates were set from June 26 to August 22, 1985. The treatments were as follows: (1) racemic ipsenol alone; (2) ipsenol and (*S*)-(+)-ipsdienol; (3) ipsenol and (*R*)-(−)-ipsdienol; and (4) ipsenol and racemic ipsdienol. Lures were replaced on July 25, 1985.

Experiment 2 tested the effect of (*S*)-(+)-ipsdienol on the attraction of *I. latidens*. Nine replicates were set from June 4 to 18, 1985. The treatments were as follows: (1) blank control; (2) racemic ipsenol alone; (3) (*S*)-(+)-ipsdienol alone; and (4) ipsenol and (*S*)-(+)-ipsdienol.

The data were analyzed using the SAS statistical package version 5.0 (SAS Institute Inc., Cary, North Carolina). Trap catch data, transformed by ln (Y + 1) to remove heteroscedasticity, were subjected to either one- or two-way analyses of variance (ANOVA). Ryan-Einot-Gabriel-Welsch (REGW) multiple-range tests were used when $P < 0.05$.

RESULTS AND DISCUSSION

(*S*)-(+)-Ipsdienol significantly inhibited the attraction of *Ips latidens* to sources of ipsenol. In experiment 1, catches of *I. latidens* to traps baited with either racemic or (*S*)-(+)-ipsdienol were approximately 20-fold lower than those to traps baited with ipsenol alone (Figure 1). Catches to traps baited with ipsenol and (*R*)-(−)-ipsdienol were not significantly different from those to ipsenol alone. In experiment 2, in which significant levels of (*R*)-(−)-ipsdienol were not present, (*S*)-(+)-ipsdienol again significantly reduced the capture of *I. latidens* (Figure 2).

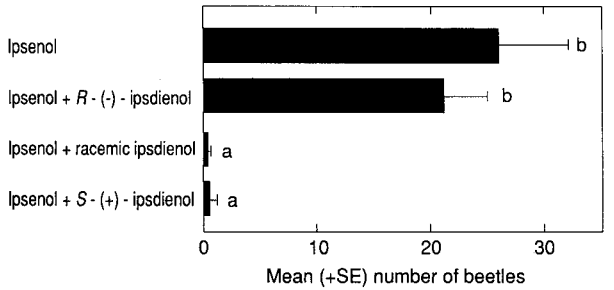

FIG. 1. The effect of chiral ipsdienol on the capture of *Ips latidens* in ipsenol-baited, multiple-funnel traps near Princeton, British Columbia, from June 26 to August 22, 1985 (N = 10). Means followed by the same letter are not significantly different at P = 0.05 [REGW multiple range test on data transformed by ln (Y + 1)].

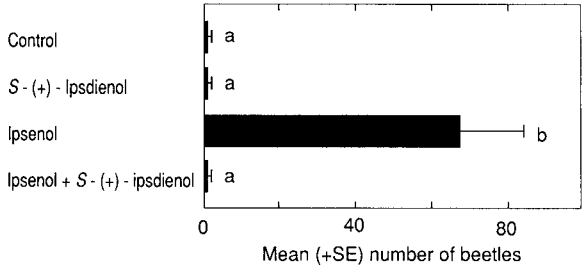

FIG. 2. The effect of the interaction between (*S*)-(+)-ipsdienol and racemic ipsenol on the capture of *Ips latidens* in multiple-funnel traps near Princeton, British Columbia, from June 4 to 18, 1985 ($N = 9$). Means followed by the same letter are not significantly different at $P = 0.05$ [REGW multiple range test on data transformed by ln $(Y + 1)$].

In south-central British Columbia, male *I. pini* produce substantial amounts of (*S*)-(+)-ipsdienol in their pheromone blend (Miller et al., 1989). Both *I. pini* and *I. latidens* breed in single-species aggregations in the phloem tissue of lodgepole pine, often in association with the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Bright, 1976; Furniss and Carolin, 1980; Wood, 1982). Both species seem to show ecological separation in their choice of breeding material; *I. latidens* seem to prefer drier phloem material than *I. pini* (Miller and Borden, 1985). It is probable, therefore, that (*S*)-(+)-ipsdienol plays a role in interspecific communication between *I. latidens* and *I. pini*, facilitating reduced interspecific competition for breeding material and/or reduced interspecific mating interference.

In contrast, *I. pini* in western United States and southeastern British Columbia use primarily (*R*)-(−)-ipsdienol as a pheromone (Stewart, 1975; Plummer et al., 1976; Birch et al., 1980; Miller et al., 1989). In these regions, (*R*)-(−)-ipsdienol may have a stronger effect on *I. latidens* than it does in south-central British Columbia. The response to (*S*)-(+)-ipsdienol is probably still present since other competing species such as *I. paraconfusus* utilize (*S*)-(+)-ipsdienol as a pheromone. Mutual inhibition between *I. pini* and *I. paraconfusus*, in these regions, is based, in part, on the chirality of ipsdienol (Light and Birch, 1977; Birch et al., 1980).

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