Potential for Biological Control of *Dendroctonus* and *Ips* Bark Beetles

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Inoculative Release of An Exotic Predator for the Biological Control of the Black Turpentine Beetle

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ABSTRACT

An inoculative release of the Eurasian predatorial beetle, *Rhizophagus grandis*, was made for control of the black turpentine beetle, *Dendroctonus terebrans* Olivier, a prominent native pest of southern pines. If this central Louisiana release proves successful, and rearing programs are perfected, further releases should expand the geographical range of *R. grandis*. Because the larval frass of other species of *Dendroctonus* is highly attractive to *R. grandis*, this exotic predator may also attack the brood of some or all of the South's *Dendroctonus* species, including that of the southern pine beetle, *Dendroctonus frontalis* .

BACKGROUND

The black turpentine beetle (BTB), *Dendroctonus terebrans* Olivier, is a native pest of pines in southern United States. It is particularly injurious in Georgia and Florida where gum naval stores operations are an important industry (Smith and Lee 1967). During turpentine operations, slash pine (*Pinus elliottii* Engelmann) and longleaf pine (*Pinus palustris* Miller) are commonly attacked and killed by the beetle. Additionally, the BTB quickly attacks trees damaged during logging operations and trees located near construction sites in urban areas. Apparently normal healthy trees may also be attacked, although BTB damage usually involves less than 10% of a stand during a single season. One "epidemic," however, in the 1950's, reportedly affected more than 25% of a single healthy stand (Smith and Lee 1967).

Although not as aggressive or wide spread as the southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, the BTB shows a preference for weakened trees, such as those damaged by fire, tapped for naval stores, or injured during logging operations. The BTB ranks third as overall damage agent among 10 major forest pests in the 13 southern states. However, according to USDA Forest Service and university researchers working in Florida and Georgia where the turpentine industry is important, BTB ranks as the most destructive pest.

Current Control Strategies

A number of control strategies are currently used to reduce bark beetle population numbers and/or to manage outbreaks. These strategies can be categorized as 1) spot control by salvage, 2) chemical treatment, and 3) preventive management of susceptible stands by silvicultural methods. Of the first two categories, rapid salvage is the preferred alternative (Swain and Remion 1981). Except for urban areas, chemical control is not widely practiced because it is not cost effective and because of environmental concerns.

Currently, preventive control by silvicultural treatment is the best overall strategy in combating outbreaks. Research over the past decade has provided successful silvicultural prevention methods that are now widely accepted (Belanger 1980, Lorio 1980). Unfortunately, economic constraints sometimes preclude use of prevention methods by many landowners in the southern United States.

Applied biological control of bark beetles is still an ignored and underdeveloped technique. Of the many organisms and allied beetle species associated with *Dendroctonus*, only native insects, mites, nematodes, and fungi have received much attention (Berisford 1980). Recent studies have been oriented toward determining specific roles and impacts of native associates so that computer models can be developed to forecast population trends. Studies have been designed to implement control strategies that can capitalize on population suppression by native natural enemies (Kinn 1984, Moser and Dell 1980). Other studies are searching for exotic or extraregional natural enemies (Moser 1981, Moser and Bogenschutz 1984, Moser et al. 1978). Although the native natural enemies may have a considerable impact on beetle populations, they still do not always control epidemic levels of the *Dendroctonus* bark beetles. It is possible then that the best hope in this area lies with the release of exotic natural enemies. One exotic insect predator, *Rhizophagus grandis* Gyllenhal (Coleoptera: Rhizophagidae), appears to have potential as a control agent (Miller et al. 1987).

The Biological Control Approach

Rhizophagus grandis is a specific predator, attacking only the spruce bark beetle, *Dendroctonus micans* (Kugelann). The distribution of both host and predator now extends westerly from eastern Siberia to France and England, south to Turkey, and to the northern tip of Norway (Bevan and King 1983). *D. micans* is the only species of *Dendroctonus* within this vast area. In the recent past, *D. micans* has expanded westerly from its Siberian origin. As the beetle invaded Europe during the past 100 years, population explosions coincided with this advance (Carle 1975). Apparently these outbreaks occurred when *D. micans* temporarily "outran" its predator, *R. grandis;* but once the predator–prey balance was achieved, *D. micans* again became endemic (J-C. Grégoire, personal communication). Presently, large-scale programs are under way to introduce the predator in spruce stands in parts of England, France, Russia, and Turkey where the scolytid is still epidemic (Grégoire et al. 1985). Efforts are especially intense in England, where *D. micans* was first discovered in 1982 (Bevan and King 1983). In 1984, 30,000 *R. grandis* adults were produced in large breeding units for distribution in England's outbreak areas of *D. micans* (Evans 1985). In 1985, 29,000 were reared in Belgium (J-C. Grégoire, personal communication).

Within the palearctic spruce forests, *R. grandis* is found in association only with *D. micans*, there being no records of its having attacked other scolytids. But perhaps this is because no other *Dendroctonus* species may be available to it within the predator's natural range in Eurasia. *R. grandis* has a high searching efficiency and is found in more than 80% of *D. micans* galleries (Grégoire et al. 1985). *R. grandis* is able to detect both larval and adult allomones of *D. micans* (Tondeur and Grégoire 1979), but *R. grandis* females will not oviposit unless larval frass of *D. micans* is present (Grégoire et al. 1984). The key allomones attracting *R. grandis* to *D. micans* galleries appear to be *exo*-brevicomin, which may be produced by *D. micans* adults, and (-)-verbenone, produced by *D. micans* larvae (Tømmerås et al. 1985).

Grégoire et al. (1981) suggested that other *Dendroctonus* species with gregarious larvae, such as BTB, might also be attractive to *R. grandis*. In a series of bioassays performed in February, 1985, J-C. Grégoire demonstrated that larval frass of three native North American species of *Dendroctonus (D. terebrans, D. frontalis,* and *D. rufipennis* (Kirby), the spruce beetle) were highly attractive to both males and females of *R. grandis*. The most surprising find was that the frass of *D. frontalis* (whose larvae are not gregarious) was also highly attractive (Miller et al. 1987). This suggests that if *R. grandis* was introduced into the United States and successfully established as a predator on *D. terebrans*, then the predator might also impact the SPB. *D. terebrans*, however, remains the primary target because it has an ecology similar to that of *D. micans*. Both BTB and *D. micans* have a long life cycle and gregarious larvae, facilitating prey exploitation by *R. grandis.*

Fig. 1. Male *Rhizophagus grandis* in gallery of *Ips grandicollis* inside phloem sandwich (USDA Forest Service photo).

It should be mentioned at this point that in 1933 and 1934 about 800 specimens of an unidentified *Rhizophagus* from England were released in Quebec, Canada, against the spruce beetle in an outbreak area, but the introduced beetles failed to become established. Turnock et al. (1976) classified this release as a futile colonization attempt, doomed by inadequate selection of natural enemies and by poor handling and release techniques. This species could not have been *R. grandis* because it was not introduced

troduced into Britain until 1982. Moreover, other known species of *Rhizophagus* are much less species specific and their predatory qualities are questionable (J-C. Grégoire, personal communication). Specimens of *R. grandis* were sent to the United States on three occasions (1976-78) for laboratory tests against North American *Dendroctonus* species, but none were released (Coulson 1981). The Canadian Forestry Service at Victoria B. C. has imported individuals to control *Dendroctonus ponderosae* Hopkins (H. A. Moeck, personal communication).

Fig. 2. Young BTB larvae feeding gregariously in phloem sandwich. Below are an adult and two larvae of *Rhizophagus grandis* (USDA Forest Service photo).

This biological control agent, if successfully established, should spread throughout the host's range, effecting widespread control that is cost effective. Theoretically, *R. grandis* should also attack broods of the more aggressive SPB, because the predator adults are highly attracted to larval frass of the scolytid (Miller et al. 1987). Indeed, *R. grandis* adults entered SPB galleries through holes made by them, and consumed the larvae in phloem sandwiches. These sandwiches (Moser and Roton, unpublished) had been previously attacked by SPB in the field. However, *R. grandis* egg laying was not observed. The same phenomenon was observed in another sandwich field-attacked by *Ips grandicollis* (Fig. 1).

Rearing Procedures

Attempts will be made to determine the best way to rear the predators in order to build up populations for release in central Louisiana. Experience in Europe has shown that large numbers of *R. grandis* for release in the field can be artificially reared on brood of *D. micans* (Fig. 1) in spruce bolts, and by a semiartificial breeding method (Grégoire et al. 1986). This latter rearing method was first developed in Russia (Kobakhidze et al. 1968) and is currently being used in England. In 1985, the British Forestry Commission reared adults of *R. grandis* in spruce billets at a cost of about $2.50 per beetle, counting materials and labor (H. F. Evans, personal communication). For that project, a constant temperature of 20 degrees C., 65-75% R. H., and an artificial lighting regime of 18 hours/day were maintained in rearing rooms (Evans 1985).

Fig. 3. Phloem sandwich with mature BTB larvae, some of which are constructing pupal cells. Young larvae were introduced at right. They feed gregariously at first; later the older larvae disperse (USDA Forest Service photo).

In 1986 and 1987, three shipments totaling 300 hundred pairs of *R. grandis*, reared by J-C. Grégoire in Belgium, were shipped to the Alexandria Forestry Center in Louisiana to test methods of rearing the predator on BTB and SPB. Although preliminary tests showed that the predator could be reared on BTB, using both the bolt and the semiartificial methods, the latter method was chosen because using bolts was too labor intensive. Our

immediate objective was to obtain eggs of *R. grandis* so that they could be surface-sterilized in White's solution (Barras 1972), thus reducing the chances of microorganisms being introduced from Europe. *R. grandis* readily laid eggs in phloem sandwiches (Fig. 2) inoculated with about 20 BTB larvae, and one male and two females of *R. grandis* (only one pair was needed, but the extra female doubled the egg production). Young BTB larvae fed gregariously (Fig. 3) similar to those of *D. micans*, but older larvae became solitary (Fig. 2). Individual females laid as many as 133 eggs per sandwich. After 5 to 8 days the sandwiches were opened, and the easily visible eggs (Fig. 4) were collected.

After surface sterilization, the eggs were placed in polystyrene boxes where the resulting larvae were reared on the alternate food sources described by Grégoire et al. (1986). This method conserved BTB larvae that were sometimes scarce and were needed as oviposition stimuli for *R. grandis*. Although the *R. grandis* larvae would readily feed gregariously on BTB larvae inside the sandwiches (Fig. 5), the predator larvae (as well as adults, Fig. 6) could be conveniently fed a variety of foods including frozen dipterous maggots and even commercial cat food. Prepupae were placed in moist sand to pupate, after the technique described by Grégoire et al. (1986).

Fig. 4. Portion of phloem sandwich with eggs of *Rhizophagus grandis* (arrows) in BTB frass (USDA Forest Service photo).

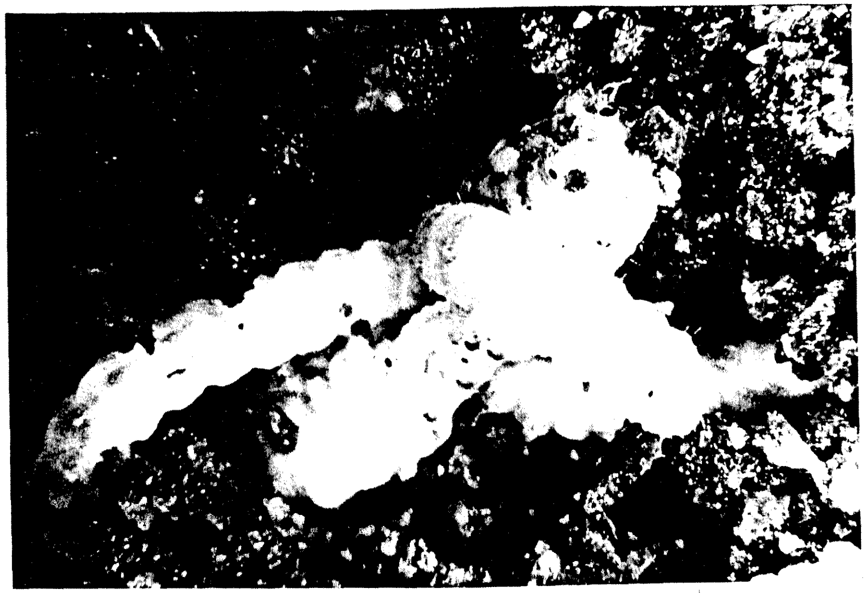

Fig. 5. Young and mature larvae of *Rhizophagus grandis* feeding gregariously on larva of BTB in artificial rearing chamber (USDA Forest Service photos).

Fig. 6. Adult of *Rhizophagus grandis* feeding on pellet of commercial dry cat food. At left (arrow) is remains of BTB larva consumed previously by the predator.

Whereas *Beauveria bassiana* (Balsamo) Vuillemin caused major rearing losses to *D. micans* and *R. grandis* brood in Europe, another pathogen [probably *Metarhizium anisopliae* (Metschinikoff) Sorokin] soon caused 100% losses to both host and predator larvae in the first Alexandria Forestry Center rearing containers. The disease was controlled in later rearings by using 0.5 g each of sorbic acid and methyl paraben, mixed with 400 g of the bark dust medium used to fill the polystyrene boxes.

Field Release Techniques

In England single pairs of *R. grandis* are placed in small plastic cups each having about 50 ml capacity. A small amount of moist sand is added. The cups are then taken into the field where the contents, including the predators, are carefully poured out at the bases of trees that have been attacked by *D. micans* (King and Evans 1985). In France, about 50 predators are placed at the base of each single infested tree, and the predators quickly vanish, running into the bark or taking flight (Grégoire et al. 1985). Both release methods take advantage of the extraordinary searching abilities of *R. grandis*.

The minimum number needed for an inoculative release is unknown, but it is probably less than the 2,350 individuals released per area in France (Grégoire et al. 1985). This is the lowest number listed in published reports for areas in which individuals were recovered the next year. However, H. F. Evans (personal communication), in England, recovered a number of *R. grandis* larvae 6 months later after releases of only 10 and 25 individuals respectively. Adults, larvae, and prepupae have been found overwintering (Grégoire, personal communication). Beirne (1975) has shown that of species (none of which were *Rhizophagus*) released for biological control in Canada, 60% of those averaging more than 800 individuals per release became colonized, but of those averaging less than 800 per release, only 15% became colonized. Hence, although it appears possible to establish *R. grandis* by using small numbers, a large release may greatly increase chances of success.

In Europe, when populations of *R. grandis* are established, they tend to "stay put" and not move rapidly into new distant areas. For this reason, a number of inoculative releases would have to be made throughout the southern United States to quickly establish the predator throughout the range of BTB.

Although the BTB is ubiquitous in pine forests of central Louisiana, high populations often occur in stumps after logging operations. Emerging adults may also attack nearby trees. It is at the interface of one of these areas and the surrounding forest that would be the ideal habitat to release the large numbers of *R. grandis* adults. As of April 1, 1988, there were about 150 pairs of adults being held in the refrigerator for release in the field. On April 7, the first 20 pairs were released in four localities of Grant Parish, Louisiana on two trees and 6 stumps similar to the method by King and Evans in England.

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