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Biological Observations on *Bdella longicornis*: A Predatory Mite in California Vineyards (Acari: Bdellidae)

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ABSTRACT. — *Bdella longicornis* L. was studied to assess its role in winter mortality of *Tetranychus pacificus* McGregor in northern California vineyards. Data indicate this predator was present in vineyards during winter and is most common on mature vine trunks near ground level; it was absent from July to September. We discuss consumption rates in the laboratory; a defensive dance; tethering behavior during prey capture; pre-oviposition and nesting behaviors; and ova development time. The predator has potential for limiting the number of tetranychids that survive subcortical diapause on vines during winter. When augmented with phytoseiids, bdellids could help minimize tetranychid numbers on vine foliage in early spring, resulting in a lowered tetranychid: phytoseiid ratio and subsequently favoring early season tetranychid control by phytoseiids.

Bdella longicornis Linnaeus is one of several bdellids that occur in California vineyards. Among other things, it preys upon *Tetranychus pacificus* McGregor, which move from the foliage of grape vines to the trunk bark in late summer or early fall where the adult female tetranychids overwinter. Little attention has been paid to the winter mortality of spider mites, especially that caused by the numerous subcortical predators on grape vines. This is due, at least in part, to the difficulties of sampling and assessing subcortical habitats accurately, without plant damage. Although bdellids have been successfully used (Wallace and Walters, 1974), surprisingly little is known of their biology. Various bdellids are known or speculated to prey upon tetranychids (Snetsinger, 1956; Gonzales, 1961; Wallace and Mahon, 1972, 1976).

Smith (1954) suggests that bdellid predation causes considerable winter mortality for *T. pacificus* on grapes, making it impossible to forecast early season levels of tetranychid infestation based on the previous year's densities. Early season tetranychid density is important

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if biological control by phytoseiids is anticipated. If the tetranychid: phytoseiid ratio exceeds ca. 40:1 shortly after foliation, the phytoseiid's numerical response is inadequate to suppress the spider mites.

Since bdellids have been successfully used as biological control agents and have been suspected of causing winter mortality of tetranychids, we investigated the occurrence and behavior of the most common bdellid, *Bdella longicornis*, in California north coast vineyards.

METHODS AND MATERIALS

Bdella longicornis was studied in two Napa Valley, California, vineyards from November 1972 to March 1974. Field sampling (1000-1800 h) typically involved 10 randomly selected vines, but intervals were irregular over the study period. Quantification of seasonal variation in bdellid densities is expressed as the number of individual bdellids per vine encountered per 10 minute search. Variation due to sampling technique was minimized, with only one sampler (JTS) involved. However, the relative densities may be slightly biased towards exfoliating bark and loose crown debris, since potential damage to premium vines necessitated minimal bark stripping injury.

Total (recoverable) bdellid densities were determined during January 1974 for eight mature (ca. 50 yr. old) vines that had been removed for vineyard management. Sections (25 cm long) from these vines representing crowns, midheight and ground-level trunks, were placed in a Berlese funnel; Friedman's test and Mann-Whitney's U-test were used in analysis ($n = 8$; $\alpha = 0.01$ and 0.15 , respectively).

Laboratory observations were made at $T = 22 \pm 2^\circ \text{C}$ ($\bar{X} \pm \text{s.d.}$), $\text{RH} = 80\%$. Bdellids were isolated (except interaction observations), and cultures were sorted in the dark. Laboratory test to determine bdellid substrate preferences and observations on the location of tethered prey were analyzed using Chi-square ($n = 20$, $\alpha = 0.05$).

Bdellids were kept on a 2 cm diameter disc (0.05-0.08 mm thick) punched from exfoliated vine bark. The bark disc was pinned midway on an insect pin and isolated by petroleum jelly above and below. Each pin was inserted into a small cork affixed to the center of the inside of a jar lid, which was capped to its jar with the pinned bark inside. Holes in the jar lids facilitated humidity exchange, and jars were kept in a closed chamber with controlled humidity. This arena represented the mites' natural substrate and could be easily handled and examined under a microscope from any angle. All mites were accounted for during laboratory study, proving the cage design effective.

RESULTS AND DISCUSSION

Vineyard seasonality and distribution

Bdella longicornis was most frequently encountered in vineyards on older vines with large amounts of exfoliating bark. It occurred on the main trunk, especially at ground level and on crowns, but was absent from branches. It was found less commonly in the soil surrounding vine bases. Few or no bdellids were found on younger vines (under 10 yrs.) with characteristically less exfoliating bark.

Bdella longicornis' presence in California north coast vineyards was correlated with the northern California winter rainy season. The predator was found in vineyards from October through June (Fig. 1). Relative densities were highest in January and began to fall in late February or early March. It was absent from July through September. We are uncertain if this absence represents a migration to the soil or a summer diapause. No bdellids were found then in the soil surrounding vine bases, nor were diapausing individuals encountered. Other bdellids have been noted to prefer cool and moist conditions (Currie, 1934), and a summer diapause has been speculated for another bdellid (Snetsinger, 1956). We found immature stages of *B. longicornis* in vineyards from January through April. Atyeo (1960) found immature stages of bdellids as early as February.

Vineyard densities

We determined absolute (recoverable via Berlese funnel) bdellid densities on eight mature Zinfandel vines during January 1974 for sections of crown and both midheight and ground-level trunks. Fig. 2 shows bdellid counts per section and area per bdellid. Area calculations

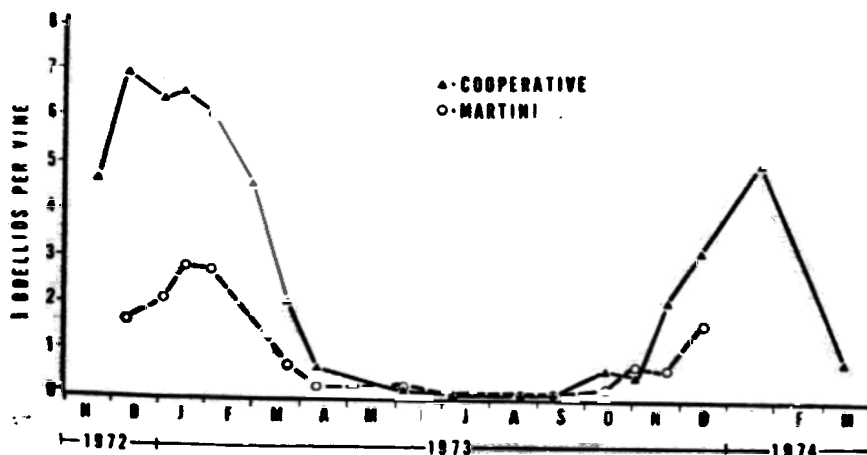


Fig. 1. Relative seasonal densities of *B. longicornis* in the Napa Valley Wine Cooperative vineyards (black triangles) and Louis Martini vineyards (white circles), St. Helena, California; expressed as mean number of bdellids per 10 minute search per vine.

excluded bark fissures and exfoliations. Data ($\bar{X} \pm \text{s.d.}$) indicate that ground-level trunk sections averaged 8.3 ± 4.7 bdellids with $92.9 \pm 69.0 \text{ cm}^2/\text{bdellid}$; midheight trunk sections averaged 3.4 ± 2.9 bdellids with $149.8 \pm 67.6 \text{ cm}^2/\text{bdellid}$; crown sections averaged 6.4 ± 5.3 bdellids with $156.2 \pm 137.2 \text{ cm}^2/\text{bdellid}$.

Friedman's test showed densities varied significantly ($\alpha = 0.01$, $n = 8$) among the three section classes. Mann-Whitney's U-test, conducted between section classes in paired fashion, showed counts differed significantly ($\alpha = 0.05$, $n = 8$) between ground-level trunks versus midheight trunks and between ground-level trunks versus crowns, but not between midheight trunks versus crowns. Using the latter analysis, densities differed significantly between ground level trunks versus midheight trunks and midheight trunks versus crowns, but not between ground level trunks versus crowns.

The bdellid distribution observed reflects the density of various available prey on the vine. Numerous soil associated prey, especially Collembola, are most common at ground level on vines. The bdellids' unique and extremely fast tethering capture method (see below) is especially suited for evasive prey, and its sluggish gait does not

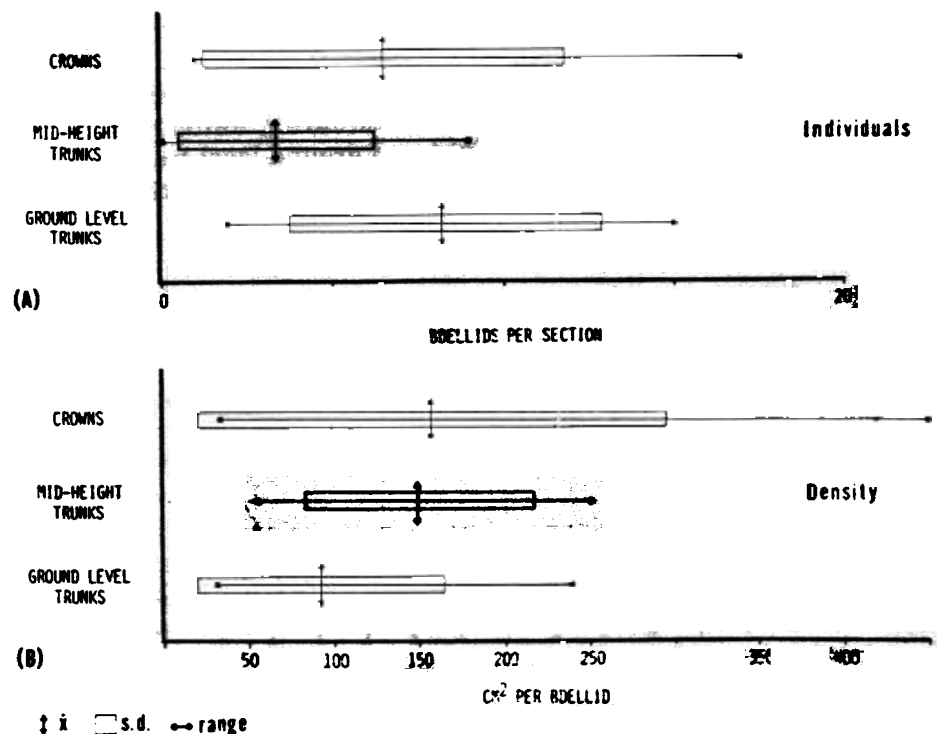


Fig. 2. Bdellid numbers and densities on vines: (A) number of individuals per sample section on vines; (B) area per bdellid (omits two vine sections lacking bdellids).

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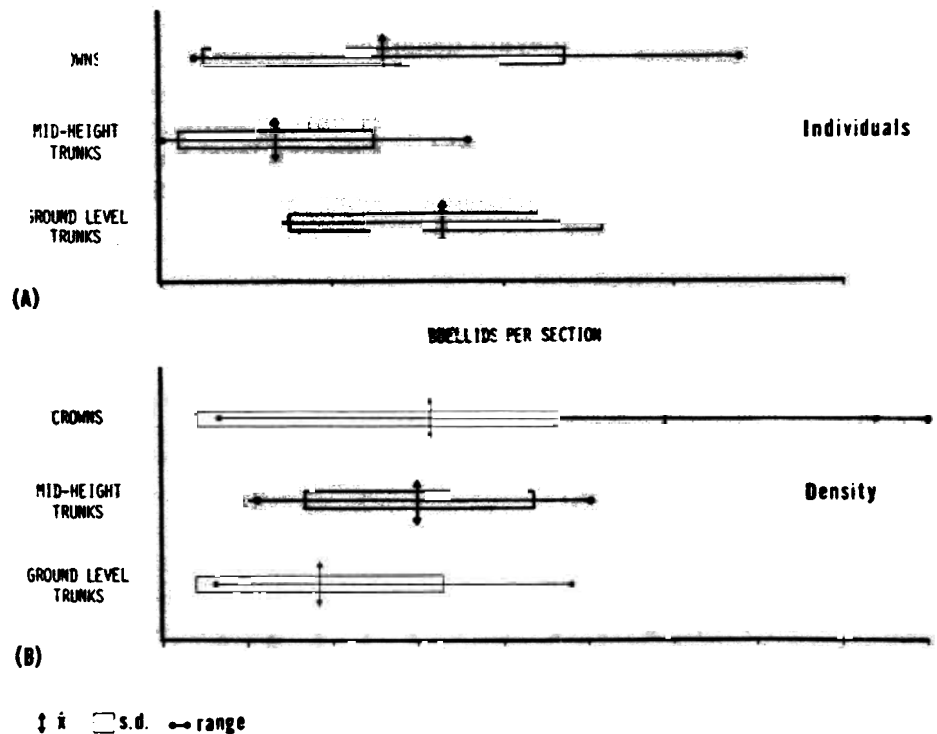


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handicap it. In fact, very rapid mites (e.g., *Anystis agilis* Banks) often cannot successfully capture Collembola (Sorensen et al., 1976). We observed *B. longicornis* to easily subdue podurids, entomobryids and smynthurids. Numerous reports of bdellids preying on Collembola exist (Wormersley, 1933; Wallace, 1974; Wallace and Walters, 1974; Wallace and Mahon, 1972, 1976).

Although bdellids on crowns were significantly less numerous than on ground level trunks and only insignificantly more numerous than on midheight trunks, their effective density was approximately equal to those on ground-level trunks. The crown of older vines accumulated debris and moss, and the potential prey fauna (especially psocids) was more numerous there than on midheight trunks. The lower number and effective density of bdellids on midheight trunks reflects reduced prey numbers there. We presume the predator's vertical distribution does not change over the day because of the bdellids sedentary behavior and slow gait; no evidence was found to the contrary.

Substrate preferences

Laboratory tests were conducted to determine *B. longicornis*' substrate preferences for a variety of textured or smooth, natural or artificial surfaces. Although bdellids spent more time on bark and coarsely aggregated vineyard soil than on other substrates tested, these preferences were not significant (Chi-square; $\alpha = 0.05$, $n = 20$). In the laboratory under dark conditions, bdellids spent significantly more time in concealment sites (fissures, crevices, pits) than in open situations, both in the presence and absence of prey.

Predatory behavior and consumption rates in the laboratory

Twenty adult *B. longicornis* were offered adult female *Tetranychus urticae* Koch to determine consumption rates. Ten prey were offered to each bdellid isolated on a 2 cm bark disc (number of prey maintained daily) and dead and collapsed tetranychids were removed. Consumption rates ranged from 1.8 to 3.3 tetranychids/day/bdellid and averaged 2.6 ± 0.4 ($T = 22 \pm 2$ C, RH = 80%).

Consumption rates published for various other bdellid species are scarce and differ widely among species. Snetsinger (1956) found that *Spinibdella depressa* (Ewing) required three or more mite ova or two or more larval mites to complete larval development, and that each nymphal stage required two or more nymphal or adult prey mites to complete each stadium. Wormersley (1933) observed one nymph of *Biscirus lapidarius* Kramer to consume 18 immature clover springtails on each of three successive days.

During laboratory observations we noted each isolated *B. longicornis* had one or two favored concealment places, usually crevices on the bark disc. Furthermore, the vast majority of tetranychid corpses were

tethered adjacent to these sites rather than in open situations; significant with Chi-square ($\alpha = 0.05$, $n = 20$). The consumption rates observed, while certainly a function of metabolic need and temperature, also undoubtedly reflect the relative encounter rate due to prey density. Laboratory temperatures were higher than the average winter temperature in north coast vineyards (22°C versus $< 14^{\circ}\text{C}$); therefore, our rates should be higher than those occurring in vineyards.

Tethering behavior

While bdellids are known for their tethering of victims with silken lines, relatively little is known of the morphology and behavior involved. Morphological descriptions of the spinning organs and their locations are given by Ehara (1960) Alberti (1973) and Alberti and Ehrnsberger (1977).

Kinn and Doult (1972) thought that *B. longicornis* squirts the silken tether at its victims after initial contact with the labial palpi. Alberti and Ehrnsberger (1977) state that after contact with the labial palpi this species and two other bdellids lunge forward with a lightening fast action, apply a blob of fluid to their victim and then draw out a silken line which is attached to the substrate.

Our observations confirm the latter. We observed the tethering behavior of *B. longicornis* to consist of five phases of extremely rapid movement: (1) prey are recognized after contact with the predator's labial palpi; (2) the bdellid rocks its entire body backward, usually with its feet firmly on the substrate; (3) the predator lunges forward touching the tip of its gnathosoma to the victim and fastens the silken tether; (4) the bdellid retracts slightly more slowly, drawing its gnathosoma down and back to contact the substrate, while spinning out the tether line and anchoring it; (5) the predator releases the tether line and resumes a normal posture.

Approximately 60+ percent of tethering actions involved the victim's appendages. After the initial tethering, bdellids circle the prey while facing it and continue to tether several additional spots. These subsequent tetherings are also usually an appendage. After initial contact a high percentage (80+%) of accurately placed tether lines are affixed to the wildly waving tips of the victim's legs. Therefore, we suspect that vision is important in subsequent tethering actions.

Alberti and Ehrnsberger (1977) state the physical qualities of the drawn out tether line change with time and that it is initially quite sticky and capable of further entanglement. We did not observe this.

After tethering, feeding may be intermittent with the prey remaining alive between feeding. Bdellids that were well fed often tethered victims only once after encounter and frequently never returned to feed. Bdellids nearly always tethered victims upon encounter, whether they fed afterwards or not. This suggests that tethering may represent a defensive reaction to surprise encounter, as well as a capturing behavior. In any

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event, tethered spider mites that were not fed upon seldom survived and usually remained tethered to their capture spot.

Alberti and Ehrnsberger (1977) believe that the fluid secreted during the tethering action is metered out, and the amount of fluid applied when tethering victims is considerably larger than that applied during other silk spinning activities, such as nest fabrication. They also state that the total volume of fluid applied over several tethering attacks during a relatively short time appeared to be more than the secretory gland could hold. We observed that bdellids that were repeatedly offered or disturbed by spider mites could tether up to 30 prey around themselves within five minutes. Predators teased with the tip of a brush frequently completed 20 or more successful tetherings before retreating but thereafter seldom initiated more tetherings on the pursuing brush. We are uncertain if cessation of attack was due to expiration of secretory fluid.

Bdellid interaction and defensive behavior

In the laboratory when two adult *B. longicornis* met unexpectedly on an exposed surface, one or both would often initiate an attack, resulting in either or both being tethered to the substrate. Several such pairs ultimately died. When only one was tethered, the victor was frequently cannibalistic.

Wandering bdellids approaching too closely to another entrenched in a concealed location were usually tethered and cannibalized. However, when two bdellids occupying different portions of a common bark crevice met, a defensive "dance" resulted and attacks never occurred. At these contacts each bdellid quickly retracted repeatedly every one to two seconds, while waving its labial palpi and holding its gnathosoma elevated. These bdellids undertook only phases 1 and 2 of the tethering behavior sequence. The dance continued until one or both mites retreated in the crevice, usually within one minute. This behavior may represent a territorial display; when it occurred mites rarely encroached into each other's areas (boundary defined as interaction point). If subsequent intrusion over the interaction point occurred, the defending bdellid always initiated the dance and was more energetic in performance and triumphant.

Nesting, pre-oviposition behavior and ova development

Alberti and Ehrnsberger (1977) document nesting behavior in bdellids and state that less secretory fluid is applied to the substrate per application during nest building than during tethering attacks. We observed female *B. longicornis* spinning silken nest chambers within bark crevices in the laboratory during January. Silk was spun from the gnathosoma to form an ultra-fine, irregular mesh which covered all the bark's surface and gaps. Completed nests totally enclosed females. Nest size (volume enclosed) typically varied from roughly 2-20 times the size

of the female. Nest size appeared partially dependent upon the physical dimensions of substrate irregularities. Enclosures with smaller volumes were more frequently constructed in more open sites. Larger nests with more room for movement were usually made between layers of bark exfoliations. Females removed from nests after nest completion usually began construction of a second nest within a week. The size of such subsequent nests, however, varied considerably from that of the original nest.

Females were generally inactive within nests but were defensive if the nest netting was disturbed. They reinforced or repaired the netting if it was disturbed, even if not damaged. No prey corpses were provisioned during nest construction, and nesting females did not normally feed. However, females did lance tetranychids that were forced against the nest. These were secured to the netting and intermittent feeding followed.

Female bdellids that laid ova did so three to seven days after nests were completed. Some females (4) built nests but abandoned them without laying ova. All ova were laid singly within nests, but were usually grouped together. Ovipositing females (7) laid five or fewer ova, and averaged one ova per 1.6 days. One female laid 15 ova within a three-day period. Oviposition was preceded by a gently rocking anteroposterior motion involving body levitation and depression. During this rocking, the body was lowered so the setae on the abdominal venter contacted the substrate. Ova were elliptical and initially translucent white but changed to translucent yellow after two days. After five days an orange embryo was evident beneath the chorion. The prelarval phase began six to seven days after oviposition, and larvae enclosed at 11 to 12 days. No cannibalism of, or by, immatures was observed.

CONCLUSIONS

Bdella longicornis is a minor predator of tetranychids in California vineyards. This bdellid augments the phytoseiid biological control system for spider mites in vineyards, especially on older vines. While phytoseiids limit tetranychid densities on grape foliage in early spring, their numerical response hinders effective suppression of tetranychid population growth if the tetranychid:phytoseiid ratio exceeds ca. 40:1. *Bdella longicornis* limits early season tetranychid densities by reducing the number of tetranychid females which successfully overwinter subcortically on grape vines, thereby lowering the tetranychid:phytoseiid ratio at early season bud-break.

Bdella longicornis is compatible with phytoseiid use, especially *Metaseulieus occidentalis* (Nesbitt), since the latter spend winter diapause in bud scales on the canes, where the bdellids are absent.

Although the tethering ability of this bdellid allows a highly favorable functional response to increasing prey density, its limited mobility

(concealment-ambush strategy) in the subcortical habitat would limit encounters with non-active prey. We suspect that in vineyards this predator primarily utilizes psocids and Collembola due to its distribution on vines.

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