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Some sawfly larvae survive predator-prey interactions with pentatomid

Picromerus bidens

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19 **Abstract**

20 Most Asopinae stinkbugs (Hemiptera: Pentatomidae) prey on other insects, including sawfly
21 larvae (Hymenoptera: Symphyta). Sawfly larvae of the Argidae and Pergidae contain toxic
22 peptides, but whether they are defended against stinkbugs remains poorly studied. A
23 literature survey indicates that no publication is devoted to laboratory tests specifically
24 using these sawflies against stinkbugs. Here, laboratory bioassays were made with the
25 stinkbug *Picromerus bidens* and four sawfly species at last larval instars: *Arge ochropus*
26 (Argidae), *Arge pagana* (also tested at medium instars), *Lophyrotoma zonalis* (Pergidae), and
27 *Allantus rufocinctus* (Tenthredinidae). Following 24 h of possible predator-prey interactions,
28 no larvae of *A. rufocinctus* survived, whereas most or all larvae of the other sawfly species
29 did survive and were still alive 48 h later. When feeding on an argid or pergid larva, the
30 feeding periods lasted on average 6–20 s only, some bugs removing their rostrum and
31 abruptly backing away. Full-grown larvae of *A. pagana* were attacked less than younger
32 ones. It is likely that the tested Argidae and Pergidae are well defended against *P. bidens* by
33 potent, internal antifeedants, while defensive body movements combined with a large body
34 size play a secondary role.

35

36 **Keywords** Argidae; Pergidae; Bioassays; Antifeedant; Chemical defence

37

38 **Introduction**

39 Asopinae stinkbugs (Hemiptera: Pentatomidae) are important predators, especially of
40 lepidopteran, coleopteran and hymenopteran (De Clercq 2000). Stinkbugs include generalist
41 predators living in various habitats, but also more specialized species occurring in a few
42 habitats where prey species diversity is rather low. Stinkbugs on a preferred host plant may
43 specialize, at least temporarily, on phytophagous prey species related to these plants. Thus,
44 most stinkbugs are opportunistic in their food preferences. This is the case for *Picromerus*
45 *bidens* (Linnaeus, 1758) which feeds on several insect orders (De Clercq 2000).

46 Sawfly larvae are phytophagous hymenopterans preyed upon by many predators, and
47 they are defended by a diversity of defence mechanisms often based on chemicals (Boevé
48 et al. 2013). Most species among the sawfly families Argidae and Pergidae contain toxic
49 peptides that are lethal to mammals and assumed to be distasteful to invertebrate

50 predators such as ants (Petre et al. 2007; Boevé et al. 2014). No studies, however, have
51 specifically considered the effectiveness of such chemical defences on attacking stinkbugs.
52 Published field observations and laboratory tests on stinkbugs–sawfly larvae interactions
53 are often related to sawflies of economic importance, typically as forest pests with an eye
54 toward using stinkbugs for biocontrol (De Clercq 2000; Table 1).

55 Here, literature references were compiled into a list (Table 1), to introduce and
56 complement a discussion about bug–sawfly interactions. Laboratory bioassays were
57 performed in which two argid, one pergid and one tenthredinid species were offered to *P.*
58 *bidens*. The predator–prey interactions and survival rates of both antagonists were recorded.
59 The potential impact of the toxic peptides on the stinkbugs is discussed.

60

61 **Materials and Methods**

62 Laboratory bioassays were performed with sawfly larvae collected in the field and
63 maintained in plastic boxes containing fresh leaves of their host plant. Four sawfly species
64 were collected: the argids *Arge pagana* (Panzer, 1797) and *Arge ochropus* (Gmelin, 1790) in
65 Uccle, Belgium, on *Rosa* sp. (Rosaceae), the pergid *Lophyrotoma zonalis* (Rohwer, 1910) in
66 Brisbane, Australia, on *Melaleuca quinquenervia* (Cav.) S.T.Blake, 1958 (Myrtaceae), and the
67 tenthredinid *Allantus rufocinctus* (Retzius, 1783) in Uccle on *Rosa* sp. The sawfly larvae were
68 tested during their last larval instar, which corresponds to instar V or VI (L5-6) in *A. pagana*
69 (see Petre et al. 2007). This species was also tested at instar III to V (L3-5). Thus, four test
70 groups were used plus the tenthredinid as a control group.

71 *Picromerus bidens* individuals were received at the end of nymphal instar IV from a
72 rearing maintained at Ghent University (Belgium). They received caterpillars of *Galleria*
73 *mellonella* (Linnaeus, 1758) as food. Bugs having reached the adult stage (instar V) during
74 the night were isolated in the morning and kept without food. These individuals were used
75 in the test only once, five hours after isolation. The bugs were maintained in a climate
76 chamber at 15–20 °C during day and night, but at 20–25 °C during the day of testing.

77 Sawfly larvae were tested in cylindrical plastic containers of 3 cm diameter and 7 cm
78 height, with a 1 cm thick moistened plaster layer on the bottom. The test started ($t = 0$) by
79 placing a single sawfly larva in the plastic container, together with a piece of host-plant leaf,
80 and by adding one bug to each container. This test was replicated 18 times for each sawfly

81 species/instar. The reactions of both larva and bug were noted from $t = 0$ to 30 min
82 (observation period), and the number and time of bug attacks were recorded. The length of
83 each attack was measured from the introduction of the stylet in the larval body to its
84 removal. After the observation period, the test continued up to $t = 24$ h (interaction period).
85 The survival of both the larvae and bugs was recorded at $t = 24, 48,$ and 72 h (i.e. day 1 to 3).

86 Two statistical tests were computed online: an Analysis of variance from summary data
87 (Merser and Pezzullo 2020) to compare bug feeding times across the four test groups, and a
88 Fisher exact probability test (Lowry 2020) to examine the influence of body size within *A.*
89 *pagana* on bug attacks.

90

91 **Results**

92 *Picromerus bidens* showed no signs of intoxication during or after the observation period,
93 and most if not all of them were still alive at $t = 3$ days (Table 2). Some bugs however
94 removed their rostrum and abruptly backed away when feeding on the larval content of *A.*
95 *pagana* L3-5, L5-6, or *A. ochropus*. Such a sudden rejection of a prey was never observed
96 with the sawfly larva of *A. rufocinctus*. Once it was pierced, the stinkbug never removed its
97 stylet from *A. rufocinctus*.

98 *Allantus rufocinctus* and *L. zonalis* larvae hardly moved when attacked by a bug. The
99 larvae of *A. pagana* L3-5 and L5-6 generally did not react when first approached and/or
100 attacked. But some larvae of this species were able to stop persistent attacks for a while by
101 moving their abdomen towards the bug. Compared with *A. pagana*, *A. ochropus* made more
102 violent movements of the abdomen when approached and/or attacked by a bug.

103 During the observation period, 10 out of 18 *A. rufocinctus* larvae were attacked by a bug
104 that pierced the larva only once (Fig. 1). Nine of these feeding events extended beyond the
105 half an hour of observation, making it impossible to calculate a mean feeding time for this
106 sawfly species. Feeding events lasted from 1–300 s for the four test groups, with an average
107 feeding time per group of 6–20 s (Table 2, Fig. 1). The values per group were not
108 significantly different ($F = 2.091, P = 0.106, N = 4$; Analysis of variance from summary data).
109 More larvae of *A. pagana* were attacked at L3-5 (14 out of 18) than L5-6 (4 out of 18)
110 ($P = 0.002$, Fisher exact probability test), and they were attacked more often (Fig. 1).

111 Similarly, the bugs attacked more, and more often, larvae of *A. ochropus* than those of *L.*
112 *zonalis*.

113 Following the end of the interaction period, no larva of *A. rufocinctus* survived (N = 18),
114 whereas 89–100% of the other sawfly species/instars survived (N = 18 four times; Table 2).

115

116 **Discussion**

117 At the end of the interaction period with the bug *P. bidens*, nearly all larvae of *A. pagana*, *A.*
118 *ochropus* and *L. zonalis* were alive, whereas all *A. rufocinctus* larvae were dead. Since ten
119 out of 18 larvae of this species were attacked during the observation period, the other ones
120 were most probably attacked afterwards. Similarly, it is likely that for *A. pagana* L5-6 and *L.*
121 *zonalis* several larvae were first attacked after the observation period. In any event, the high
122 survival rate in the four test groups contradicts the statement that "All [prey] larvae bitten
123 or sucked even very slightly [by *P. bidens*] are doomed to certain death" (Mayné and Breny
124 1948, p. 203).

125 The bugs that attacked a larva of *A. ochropus* or *A. pagana* L3-5 fed at least twice on
126 average, indicating that they were hungry. Their feeding time was similar across the four
127 test groups and did not exceed 20 s on average. This is surprisingly short compared with the
128 feeding time on *A. rufocinctus*, and feeding on other insects can last hours (Javahery 1986).
129 Moreover, feeding trials here could end abruptly with the bug suddenly distancing itself
130 from the larva.

131 Many sawfly larvae use chemicals in anti-predator defences, but they are preyed upon by
132 bugs anyway. The Nematinae (Tenthredinidae) emit volatiles from ventral glands, whereas
133 other tenthredinids especially among the Blennocampinae and Athaliinae easily bleed
134 hemolymph containing harmful plant-derived compounds (Boevé et al. 2013). The
135 Diprionidae as well as the Perginae and Pergulinae (Pergidae) regurgitate an entangling oily
136 fluid (Eisner et al. 1974; Morrow et al. 1976; Pereira et al. 2008). A literature survey
137 indicates, however, that hemipteran predators are frequently recorded preying on
138 Diprioninae (Diprionidae) in field and/or laboratory conditions (Table 1). Some tenthredinids
139 are less easily preyed upon, but the influence and value of specific protective chemicals
140 against bug predation remain unclear. A few publications mention Pentatomidae and a
141 Reduviidae feeding on Argidae or Pergidae larvae, but whether toxic peptides occur in these

142 sawflies is not always known (Table 1). Furthermore, the asopine *Podisus maculiventris* (Say,
143 1832) clearly rejected larvae of *A. pagana* (own laboratory observations).

144 The aforementioned short feeding time and sudden rejection by the bugs suggest the
145 existence of an internal chemical defence in the tested Argidae and Pergidae species. The
146 total quantities of toxic peptides are ca. 50 µg per larva in *A. ochropus*, 75–80 µg per larva in
147 *A. pagana* L5-6, and 1300–1500 µg per larva in *L. zonalis* (Boevé et al. 2014), whereas no
148 data exist about chemical compounds that would be used in defence by *A. rufocinctus* and
149 *A. pagana* L3-5. Toxic peptides are predominantly detected in the integument and
150 hemolymph of *A. pagana* and *L. zonalis* (Boevé and Rozenberg 2020). Thus, the toxins from
151 the hemolymph probably inhibited stinkbug feeding.

152 Larvae of *A. pagana* were more often attacked at L3-5 than L5-6, which may be explained
153 by a larger body size and/or a greater effectiveness of body movements in the older larvae.
154 *Arge pagana* L5-6 and *L. zonalis* were less often attacked than the other test groups,
155 suggesting that a larger larval body size hampered the stinkbug attacks. Indeed, *P. bidens*
156 prefers small to medium-sized and slow moving prey items (Mayné and Breny 1948;
157 Javahery 1986). Generally, body movements are like a double-edged sword from a prey's
158 perspective. They stimulate the predator to attack (Javahery 1986) while they can also
159 physically repel and dislodge predators, especially small ones such as invertebrates.
160 Conversely, some sawfly larvae remain immobile even if attacked (Boevé et al. 2013). Here,
161 a large body size combined with body movements may have partially mitigated predation
162 risks. Asopines generally dislike hairy prey (Whitmarsh 1916; Oetting and Yonke 1971;
163 Senrayan and Ananthkrishnan 1991) and they encounter difficulties in attacking gregarious
164 prey species (Tostowaryk 1972; Morrow et al. 1976; McClure and Despland 2011). Since
165 nearly all larvae of the four test groups survived the bioassays, body size and movements
166 appear to be of secondary importance in the defensive strategy of Argidae and Pergidae
167 larvae containing toxic peptides.

168 Non-chemical factors probably play a greater role in natural conditions than in the
169 present experimental conditions where sawfly larva and stinkbug were closely confined,
170 during 24 h. The overall defensive effectiveness in nature is expected to increase
171 accordingly. At an ultimate level, however, it is assumed that the evolution of
172 gregariousness and body appearance has been driven by the presence of the toxins in these
173 two sawfly families (Boevé et al. 2018a). Generally, the bioassay results presented here and

174 published data about bug–sawfly interactions suggest that these toxins constitute a rare
175 and potent antifeedant at least against *P. bidens*. This conclusion should be confirmed by
176 further research that directly tests the toxins on stinkbugs.

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179 **Compliance with ethical standards – Declarations**

180 **Funding** Not applicable.

181 **Conflicts of interest** The author declares that no competing interests exist.

182 **Ethics approval** Not applicable.

183 **Consent to participate** Not applicable.

184 **Consent for publication** Not applicable.

185 **Availability of data and material** The raw dataset is available upon request.

186 **Code availability** Not applicable.

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330

331

332 **Table 1** Literature data about interactions between sawfly larvae and hemipteran predators

333

Sawfly family/ subfamily	Sawfly species (= synonym)	Hemiptera	Data and observations (original reference)	Condi- tion	Sawfly defence	Reference
Argidae						
Arginae	<i>Arge salicis</i> Rohwer, 1912 (= <i>Hylotoma pectoralis</i>) ¹	“pentatomid”	A single bug species observed to suck half-grown larvae	Field	–	(Schwarz 1909)
Diprionidae						
Diprioninae	<i>Microdiprion pallipes</i> (Fallén, 1808) (= <i>Diprion (Microdiprion) pallipes</i>)	<i>Picromerus bidens</i>	Bugs destroy 30-40% of larvae	Field	–	(Mallach 1974)
Diprioninae	<i>Diprion similis</i> (Hartig, 1836) (= <i>Diprion simile</i>)	<i>Picromerus bidens</i>	Two bug specimens preying on larvae	Field	–	(Lattin and Donahue 1969)
Diprioninae	<i>Diprion similis</i>	<i>Podisus serieventris</i> , <i>P. placidus</i> , <i>P. modestus</i> , <i>P. maculiventris</i>	Bugs commonly feed on larvae in the field, and were reared on larvae	Field & lab	–	(Coppel and Jones 1962)
Diprioninae	<i>Gilpinia frutetorum</i> (Fabricius, 1793)	<i>Picromerus bidens</i>	Bugs feed on larvae	Field	–	(Kelton 1972)
Diprioninae	<i>Neodiprion excitans</i> Rohwer, 1921	<i>Arilus cristatus</i> (Reduviidae), <i>Podisus fretus</i>	Predators of the larvae included a heavy population of the wheel and pentatomid bug	Field	–	(Hetrick 1959)
Diprioninae	<i>Neodiprion lecontei</i> (Fitch, 1858)	<i>Apateticus bracteatus</i> , <i>Apiomerus crassipes</i> (Reduviidae), <i>Arilus cristatus</i> (Reduviidae), <i>Nabis ferus</i> (Nabidae), <i>Podisus serieventris</i> , <i>Pselliopus cinctus</i> (Reduviidae), <i>Sinea diadema</i> (Reduviidae), <i>Zelus socius</i> (Reduviidae), <i>Apateticus</i> sp., <i>Podius</i> sp.	Association	Field	–	(Benjamin 1955)
Diprioninae	<i>Neodiprion nanulus</i> K. Schedl, 1933 (= <i>Neodiprion nanulus nanulus</i>)	<i>Euschistus variolarius</i>	A bug was collected feeding on a fifth instar larva	Field	–	(Kapler and Benjamin 1960)
Diprioninae	<i>Neodiprion pinetum</i> (Norton, 1869)	<i>Podisus placidus</i>	Bugs preying on sixth instar larvae	Field	–	(Rauf and Benjamin 1980)
Diprioninae	<i>Neodiprion pratti</i> (Dyar, 1899)	<i>Apiomerus crassipes</i> (Reduviidae), <i>Pselliopus cinctus</i> (Reduviidae), <i>Podisus maculiventris</i>	The bugs attacked mature larvae	Field	–	(Knerer and Wilkinson 1990)
Diprioninae	<i>Neodiprion rugifrons</i> Middleton, 1933	<i>Podisus maculiventris</i>	Predation on larvae by stinbugs, especially <i>P. maculiventris</i> , influences sawfly populations	Field	–	(Wilkinson et al. 1966)

Diprioninae	<i>Neodiprion sertifer</i> (Geoffroy, 1785) (= <i>Diprion sertifer</i>)	<i>Picromerus bidens</i>	Sawfly infestation probably stopped by the bugs that suck out larvae	Field	–	(Forsslund 1944)
Diprioninae	<i>Neodiprion sertifer</i>	<i>Podisus placidus</i>	Bug is a larval predator associated with the sawfly	Field	–	(Benjamin et al. 1955)
Diprioninae	<i>Neodiprion sertifer</i>	<i>Rhynocoris annulatus</i> (Reduviidae)	Bug repeatedly observed emptying larvae	Field	–	(Niklas and Franz 1957)
Diprioninae	<i>Neodiprion swainei</i> Middleton, 1931; <i>N. pratti banksianae</i> Rohwer, 1925	<i>Podisus modestus</i>	Bugs usually attacks on the periphery of sawfly colonies	Field?	–	(Tostowaryk 1971a)
Diprioninae	<i>Neodiprion swainei</i>	<i>Pilophorus uhleri</i> (Miridae)	Bug as a predator of larvae at instar I & II (Smirnoff 1959)	Field?	–	(Coppel and Benjamin 1965)
Pamphiliidae						
Pamphiliinae	<i>Pamphilius betulae</i> (Linné, 1758)	“bug”	Two bugs killed each one a larva	Field?	–	(Vikberg 2002)
Pergidae						
Perginae	<i>Pseudoperga guerinii</i> (Westwood, 1880) (= <i>Pseudoperga guerini</i>) ²	<i>Leana australis</i> (Reduviidae)	Bug adult sometimes can attack a single larva of a sawfly colony	Field	+/-	(Morrow et al. 1976)
Pergulinae	<i>Haplostegus nigricrus</i> Conde, 1936	<i>Podisus nigrispinus</i> , <i>Supputius cincticeps</i> , <i>Brontocoris tabidus</i>	All <i>P. nigrispinus</i> and <i>S. cincticeps</i> died within 24 h after contact with regurgitated compounds from the larvae, whereas <i>B. tabidus</i> survived until adult stage	Lab	+/-	(Pereira et al. 2008)
Perreyiinae	<i>Heteroperreyia hubrichi</i> Malaise, 1955 ³ ; <i>Heteroperreyia kava</i> D.R. Smith, 2019 (= <i>Heteroperreyia</i> sp.) ^{1,4}	<i>Brontocoris tabidus</i>	Bug nymphs and adults feeding on larvae	Field	–	(Mc Kay et al. 2019)
Tenthredinidae						
Allantinae	<i>Monostegia abdominalis</i> (Fabricius, 1798)	<i>Podisus modestus</i>	Bugs attacked larvae, but only in no-choice tests, and rejected them after a few minutes only	Lab	+	(Tostowaryk 1971b)
Athaliinae	<i>Athalia rosae</i> (Linné, 1758)	<i>Podisus maculiventris</i>	≥50% Larvae alive or killed but not emptied after exposure to bug	Lab	+/-	(Boevé and Müller 2005)
Athaliinae	<i>Athalia rosae</i>	<i>Podisus maculiventris</i>	Sequestration of plant glucosinolates by larvae only marginally affects the development of the bug	Lab	–	(Van Geem et al. 2014)
Blennocampinae	<i>Phymatocera aterrima</i> (Klug, 1816)	<i>Picromerus bidens</i>	Bug nymph feeds on larvae	Field	–	(Butler 1923)
Blennocampinae	<i>Phymatocera aterrima</i> , <i>Rhadinoceraea aldrichi</i> (MacGillivray, 1923), <i>R. micans</i> (Klug, 1816) ⁵ , <i>R. nodicornis</i> Konow, 1886	<i>Podisus maculiventris</i>	≥50% Larvae alive or killed but not emptied after exposure to bug	Lab	+/-	(Boevé and Müller 2005)
Heterarthrinae	<i>Caliroa cerasi</i> (Linné, 1758)	<i>Picromerus bidens</i>	Bug nymphs prefer young larvae; bug adults attack and kill all larval stages	Lab	–	(Carl 1976)

Heterarthrinae	<i>Caliroa cerasi</i>	<i>Brontocoris nigrolimbatus</i>	Bug nymphs I-V consume a mean of 33 sawfly larvae, a bug adult about 146 ones	Field & lab	–	(Rebolledo et al. 2004)
Nematinae	<i>Euura pavidus</i> (Serville, 1823) (= <i>Nematus pavidus</i>)	<i>Podisus maculiventris</i>	≥50% Larvae alive or killed but not emptied after exposure to bug	Lab	+/-	(Boevé and Müller 2005)
Nematinae	<i>Nematus</i> spp.	<i>Picromerus, Podisus</i>	Bugs feeding on larvae, e.g. 1 larva / day during ca. 1 month	Field & lab	–	(Schumacher 1910)
Nematinae	<i>Euura scutellata</i> (Hartig, 1837) (= <i>Pachynematus scutellatus</i>)	<i>Pentatoma rufipes</i>	Bug nymphs and adults often feeding on larvae; nymph V consume 0.35–0.8 sawfly larva / day	Field & lab		(Gäbler 1952)
Nematinae	<i>Pristiphora erichsonii</i> (Hartig, 1837)	<i>Picromerus bidens, Pinthaeus sanguinipes</i>	<i>P. bidens</i> associated with the sawfly 7 times, destroying an entire colony once; overall mortality <5%; last nymphal stage of <i>P. sanguinipes</i> associated with the sawfly 2 times	Field	–	(Pschorn-Walcher and Zinnert 1971)
Nematinae	<i>Pristiphora laricis</i> (Hartig, 1837) (= <i>Lagaeonematus laricis</i>)	“Bugs”	Moderate destruction of larvae by bugs	Field	–	(Hein 1956)
Nematinae	<i>Pristiphora laricis</i> (= <i>Lagaeonematus laricis</i>)	<i>Picromerus bidens</i>	"The bug mimics the larvae, as was observed on the tree"	Field	N/A	(Hsin 1935)
Selandriinae	<i>Aneugmenus padi</i> (Linné, 1760)	<i>Podisus maculiventris</i>	≥50% Larvae killed and emptied after exposure to bug	Lab	–	(Boevé and Müller 2005)
Selandriinae	<i>Strongylogaster multifasciata</i> (Geoffroy, 1785), <i>Stromboceros delicatulus</i> (Fallén, 1808)	<i>Podisus maculiventris</i>	≥50% Larvae alive or killed but not emptied after exposure to bug	Lab	+/-	(Boevé and Müller 2005)
Xyelidae						
Xyelinae	<i>Pleroneura</i> spp.	"Predaceous hemipteran"	Dried and shrivelled late-instar larvae occurred occasionally and may have been killed by bugs	Field	–?	(Ohmart and Dahlsten 1979)

334

335 The list is most probably not exhaustive. The authorship of the sawfly names follows the taxonomy in Taeger et al. (2010); a synonym is given
336 between parentheses if used in the reference. Bug names have only been checked for their classification at family level. Their family name is
337 mentioned between parentheses only for non-Pentatomidae. Original data were considered as far as possible, that is, data from secondary
338 sources were generally not included. One reference (Hsin 1935) does not contain data about bugs preying on sawfly larvae, although cited for
339 that reason by other references. The published data and observations are summarized in a brief one-sentence statement, and the sawfly
340 defence is consequently judged as rather effective (+) or not (–). Not applicable (N/A).

341

342 ⁽¹⁾ Species expected to contain toxic peptides, since these are present in congeneric species (Boevé et al. 2014, 2018b).

343 ⁽²⁾ Species not expected to contain toxic peptides, since these were not detected in two species from two different genera, *Perga* and
344 *Pergagrapt*, but belonging to the same subfamily (Boevé et al. 2014).

345 ⁽³⁾ Species known to contain toxic peptides (Boevé et al. 2018b).

346 ⁽⁴⁾ The unidentified *Heteroperreyia* species mentioned in Mc Kay et al. (2019) corresponds to *H. kava* as described in Smith et al. (2019) (F. Mc
347 Kay, personal communication, 2020).

348 ⁽⁵⁾ Species where toxic peptides were not detected (Boevé et al. 2014)

349

350 **Table 2** Sawfly larvae used in the bioassays with *Picromerus bidens*, and part of the results

351

	Body length (mm)	Larvae tested	Bug feeding time (s) mean \pm SD [min. to max.]	Larvae alive at day 1/2/3	Bugs alive at day 3
<i>Allantus rufocinctus</i>	21	18	– [56 to >1800]	0/0/0	18
<i>Arge ochropus</i>	20	18	10 \pm 22 [1 to 128]	18/18/18	18
<i>Arge pagana</i> L3-5	14–18	18	20 \pm 48 [1 to 300]	18/18/18	18
<i>Arge pagana</i> L5-6	18–20	18	10 \pm 12 [1 to 35]	18/18/16	17
<i>Lophyrotoma zonalis</i>	23	18	6 \pm 3 [2 to 10]	17/17/16	18

352

353 Data about body length are from Lorenz and Kraus (1957) and own observations, and the

354 value for *L. zonalis* does not include the caudal appendage. Feeding times were measured

355 from t = 0 to 30 min, and values given as mean \pm standard deviation (SD) are also depicted

356 in Fig. 1. (–) Not calculable. Sawfly and bug survival data were gathered following

357 interactions from t = 0 to 24 h (i.e. day 1). See Fig. 1 for further results

358

359 **Figure caption**

360

361 **Fig. 1** Results from bioassays with sawfly larvae offered to *Picromerus bidens*. Larvae were
362 tested when full grown, *A. pagana* being also tested at younger instars (L3-5). Using 18
363 larvae per species/instar and tested singly against single bugs, the following measurements
364 were gathered during 30 min of predator-prey interactions: the number of larvae attacked,
365 the total number of attacks made by the 18 bugs, their total number of sudden rejections,
366 and their feeding time. The values at the right of the “total bug attacks” histogram bars are
367 the average number of bug’s feeding events per attacked larva. For more explanation, see
368 text

