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# Relative development and voracity of six species of Aphidophagous syrphids in cruciferous crops

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**Abstract.** The development and voracity of 6 species of syrphid are described and contrasted. *Eupeodes* (*Macrosyrphus*) *confrator* was larger than the other species as an adult and as a larva, and had a greater daily voracity. Size contributed greatly towards variation in longevity and voracity. All species were similar in the time-course of feeding behaviour.

**Keywords.** Aphidophagous syrphids; cruciferous crops; development; voracity.

## 1. Introduction

In the Gangetic plain and the higher altitude parts of India, *Lipaphis erysimi* (Kalt.) is a well-known aphid pest of cruciferous crops such as mustard, cabbage, cauliflower and radish (Bakhetia 1983; Ghosh and Mitra 1983). Winter crops of these vegetables and oilseeds (mustard) are seldom spared from attack by this aphid.

Although as many as 14 species of Syrphidae have been recorded as feeding on *L. erysimi* in cruciferous crops, the commonest are typically *Betasyrphus serarius* Wied., *Episyrphus balteatus* DeGeer, *Ischiodon scutellaris* Fabr., and *Eupeodes* (*Macrosyrphus*) *confrator* Wied. Various authors have studied usually single species, recording their voracity and development (Bhatia and Shaffi 1932; Rahman 1940; Rao 1969; Roy and Bose 1977; Agarwala *et al* 1981), but no experiments have compared species to gain a more comprehensive understanding of the role of syrphid larvae in aphid predation. The experiments reported here were designed to assess the predatory potential of 6 syrphid species (the above 4, plus *Allograpta javana* Wied. and *Episyrphus alternans* Macquart) feeding on *L. erysimi.*

## 2. Materials and methods

Individual eggs of each of the 6 syrphid species were collected from aphid-infested crops of mustard, cabbage, cauliflower or radish. Each of the eggs was placed on a filter paper in a clean dry Petri dish. A wad of moistened cotton was provided and replaced each day to maintain humidity. A known number of aphids of known instars (normally 3rd or 4th) and weights was provided each day, and observations were taken on developmental and voracity by noting the duration of each developmental stage (egg, larva, puparium) and by making daily measurements of the weight and number of aphids eaten. The lengths of larva and adult were recorded. Larval length was recorded twice, once upon emergence and again at the quiescent period before pupation. In both cases the larvae were measured when

fully extended using a mm scale. Growth rate was calculated as:

$$(\log_{10} [\text{final length} - \log_{10} \text{initial length}])/\text{days}.$$

The experiment was set up with 6–9 replications in laboratory conditions, when average maximum and minimum temperatures were 24 and 14°C respectively and relative humidities 37 and 67%. There was no mortality of larvae during the experiment.

All the data were analysed using SPSS-X programs. Two of these programs were used: MANOVA, nearly always in a two-way species × sex unbalanced analysis of variance using the method of fitted constants; and ONEWAY, a one-way analysis of variance generally using a priori contrasts.

## 3. Results

Mean values for measured variables are given in table 1. An initial general point is that there do not appear to be any substantial differences between species in the relative amount of feeding done during each stage of larval development. Figure 1(A) is a plot of the proportion of feeding done at different stages of larval life, and it can be seen that all species are similar in their curves. Figure 1(B) plots the same data on semi-probability paper, demonstrating further that the amount of feeding on each day of larval development is predictable and constant between species.

The number of aphids eaten varies according to the instar of aphid offered. Many more small 2nd and 3rd instar aphids are required to complete development than the larger 4th instar aphids (figure 2). The further analysis below considers the weight of aphid mass eaten, rather than the number of aphids, in order to control the aphid size.

The statistical analysis is presented as a series of questions for clarity.

**Table 1.** Mean values of recorded measurements.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *A. javana* | m | 11·0 | 8·2 | 12·5 | 136·0 | 133·5 | 0·10 | 0·11 | 21·5 |
| | f | 10·9 | 8·5 | 10·0 | 99·6 | 101·8 | 0·11 | 0·13 | 19·5 |
| *B. serarius* | m | 13·4 | 9·2 | 13·2 | 126·5 | 124·0 | 0·12 | 0·10 | 22·5 |
| | f | 12·2 | 8·9 | 8·3 | 76·7 | 83·6 | 0·12 | 0·12 | 22·2 |
| *E. alternans* | m | 11·7 | 8·8 | 10·4 | 75·6 | 79·4 | 0·15 | 0·15 | 17·0 |
| | f | 11·1 | 8·7 | 8·4 | 69·9 | 78·6 | 0·13 | 0·14 | 19·6 |
| *E. balteatus* | m | 10·9 | 8·4 | 9·9 | 88·3 | 92·1 | 0·12 | 0·13 | 19·5 |
| | f | 10·8 | 8·7 | 8·2 | 79·1 | 82·9 | 0·11 | 0·13 | 21·3 |
| *I. scutellaris* | m | 11·9 | 8·5 | 9·8 | 72·5 | 74·6 | 0·15 | 0·15 | 19·2 |
| | f | 11·4 | 8·1 | 11·1 | 97·6 | 98·9 | 0·12 | 0·13 | 20·2 |
| *E. confrator* | m | 15·0 | 11·3 | 19·2 | 172·7 | 151·4 | 0·12 | 0·09 | 22·0 |
| | f | 14·4 | 11·3 | 18·1 | 180·5 | 162·9 | 0·11 | 0·08 | 22·8 |

1, Sex (m = male, f = female); 2, final size of third instar larva (mm); 3, length of adult (mm); 4, average daily voracity (weight of aphids per day in mg); 5, average total voracity (biomass of aphids eaten, in mg); 6, total voracity adjusted for differences in initial larval size (size upon emergence from egg); 7, growth rate (mm per day on log scale); 8, growth rate adjusted for differences in final larval size; 9, development time, egg to adult (in days).

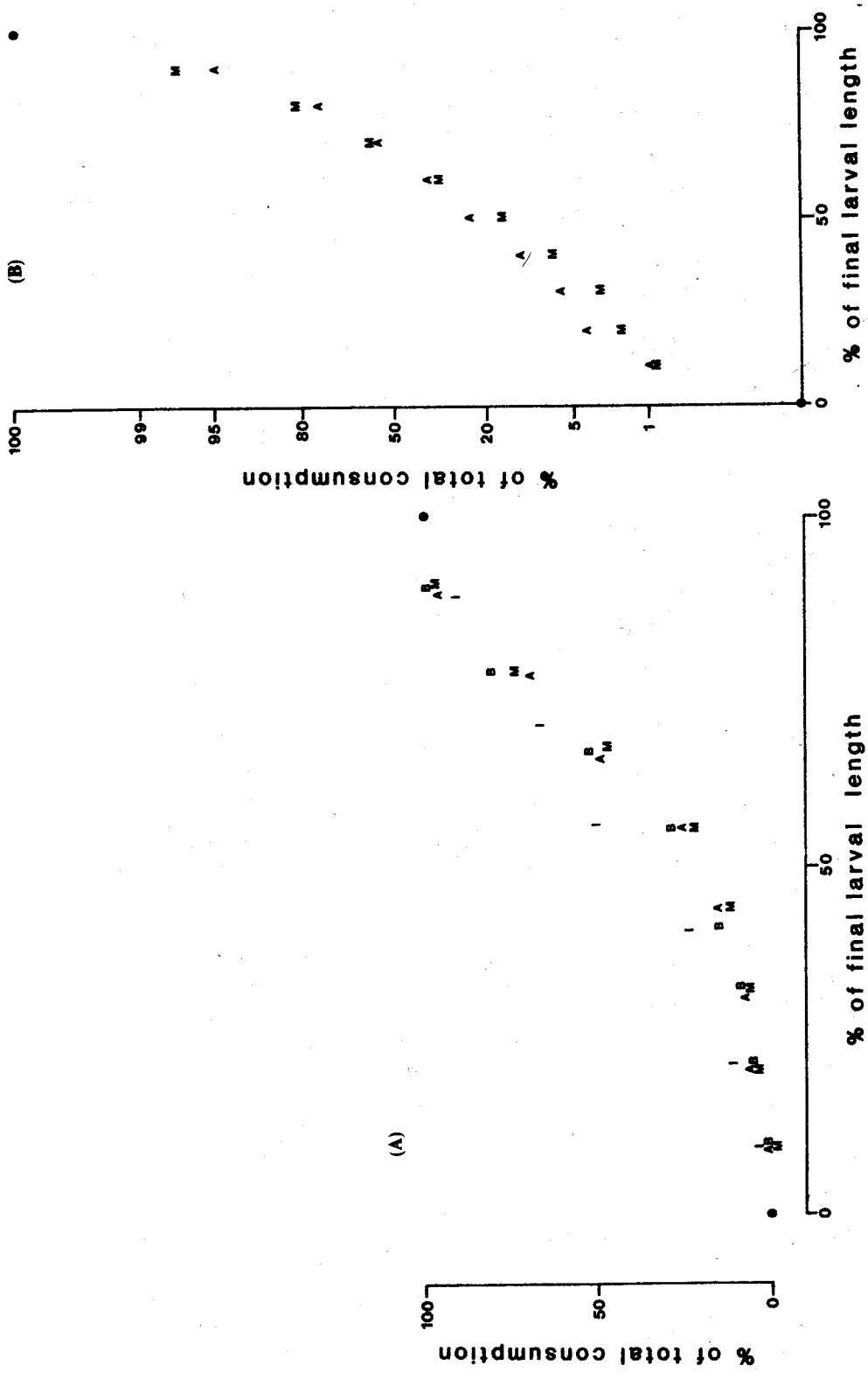


**Figure 1.** A. Development of and predation by larvae of 4 syrphid species. A, *A. javana*; B, *B. serarius*; I, *I. scutellaris*; M, *E. (M.) confrator*. **B.** The same data for two species plotted on probability paper: a slight curve probably is the best fit. A, *A. javana*; M, *E. (M.) confrator*.

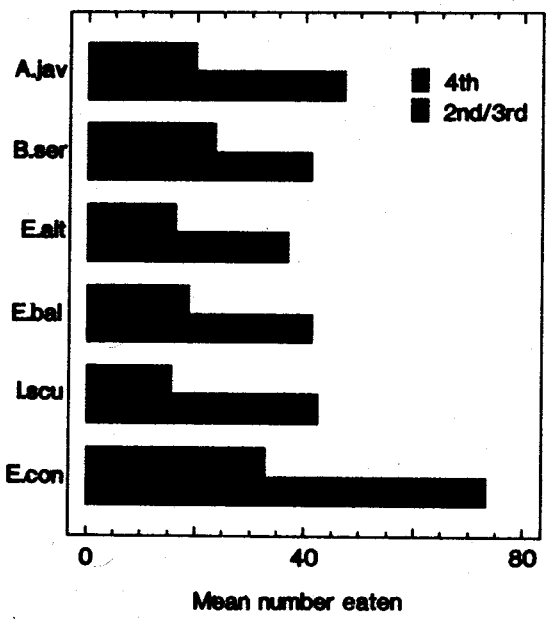


**Figure 2.** Comparison of the numbers of 4th instar *L. erysimi* as opposed to 2nd + 3rd instar, eaten by larvae of the 6 species of syrphid.

### 3.1 *Is size of all the species same?*

Adults species are significantly different in size ($F_{5,33} = 27{\cdot}35$, $P < 0{\cdot}001$), but as an overall effect the sexes do not differ in size ($F_{1,33} = 0{\cdot}07$, not significant). The interaction term is not significant ($F_{5,33} = 0{\cdot}38$), implying that the differences between the sexes in adult size are not different between species.

Since *a posteriori* tests are required to establish which species are different, an SNK procedure was used (Sokal and Rohlf 1969). This showed that *E. (M.) confrator* is significantly larger than all other species.

All the larval stage species are similarly significantly different in size ($F_{5,33} = 13{\cdot}11$, $P < 0{\cdot}001$), but neither sexes ($F_{1,33} = 2{\cdot}16$, not significant) nor the interaction ($F_{5,33} = 0{\cdot}22$, not significant) was significant. Again a posteriori SNK tests showed that *E. (M.) confrator* is significantly larger than all other species, and that *B. serarius* is larger than *E. alternans*, *E. balteatus* and *A. javana*.

Having found these differences, where appropriate we now set up an a priori contrast of *E. (M.) confrator* vs the rest, anticipating that size will cause significant differences among species for other measured variables.

### 3.2 *Do species differ in development time (egg to adult) or growth rate?*

Species differ significantly in development time ($F_{5,33} = 4{\cdot}74$, $P < 0{\cdot}001$), but there are no significant differences between the sexes ($F_{5,33} = 2{\cdot}11$, not significant) and the interaction term is non-significant ($F_{5,33} = 0{\cdot}45$). In a one-way ANOVA for development time, the contrast of *E. (M.) confrator* vs the rest is not significant.

The same pattern is evident when considering growth rates, where species differ ($F_{5,33} = 2{\cdot}53$, $P < 0{\cdot}05$), but sexes do not ($F_{1,33} = 2{\cdot}17$, not significant) and there is

no interaction ($F_{5,33}=0{\cdot}83$, not significant). A one-way ANOVA with a priori contrast of *E.* (*M.*) *confrator* vs the others shows that all the difference between species resides in this contrast ($P=0{\cdot}023$).

We then asked whether growth-rate differences were related to size differences between larvae, using an analysis of covariance with final larval size as covariate. The covariate has a highly significant regression on growth rate ($F_{1,32}=37{\cdot}7$, $P<0{\cdot}001$), but the residuals still show species differences ($F_{5,32}=6{\cdot}8$, $P<0{\cdot}001$): the effect of sex and the species × sex interaction remain non-significant. Therefore final larval size, while having a significant relationship with growth rate, fails to remove all the differences in growth rate between species.

### 3.3 *Does voracity differ between species?*

Average daily voracity (weight of aphids eaten per day) differs significantly between species ($F_{5,33}=13{\cdot}06$, $P<0{\cdot}001$), and there is a high variance ratio for the differences between the sexes ($F_{1,33}=3{\cdot}47$, $P=0{\cdot}07$) indicating that male larvae have a higher daily intake than females (table 1). A single classification ANOVA was performed with the contrast *E.* (*M.*) *confrator* vs the rest: this contrast was highly significant ($F_{4,39}=59{\cdot}14$), and no other differences remained ('rest', $F_{4,39}=0{\cdot}53$). Thus, the differences in daily voracity between species are all accounted for by one species, *E.* (*M.*) *confrator*, which has a higher daily intake rate than other species. All other species have the same daily voracity.

To determine whether this difference is entirely due to the size difference between *E.* (*M.*) *confrator* and the other species, an analysis of covariance was performed using final larval size as covariate. The covariate showed only a weak effect on daily voracity ($F_{1,32}=3{\cdot}62$, $P=0{\cdot}066$), species differences remaining ($F_{5,32}=4{\cdot}36$, $P<0{\cdot}01$). Thus the size difference does not account for the differences in daily voracity.

Total voracity over the entire larval life also differ between species ($F_{5,33}=20{\cdot}24$, $P<0{\cdot}001$); the overall difference between sexes was not significant ($F_{1,33}=1{\cdot}11$), but the interaction of species × sex was close to significance ($F_{5,33}=2{\cdot}35$, $P=0{\cdot}063$). Thus it is probable that the difference between the sexes in total voracity varies according to species: in *A. javana, B. serarius, E. alternans* and *E. balteatus*, males have a greater total intake than females, whereas in *I. scutellaris* and *E.* (*M.*) *confrator* the opposite is true.

Are these differences caused by size differences? An analysis of covariance used final larval size as covariate: in this case, the regression (covariate) was not significant ($F_{1,32}=0{\cdot}47$). A further possibility is that the initial larval size on emergence from the egg is a determinant of the eventual total voracity. An analysis of covariance found a very significant regression ($F_{1,32}=6{\cdot}17$, $P<0{\cdot}01$). As before, even when we adjust for initial larval size, species differences remain ($F_{5,32}=7{\cdot}04$, $P<0{\cdot}001$). There are no sex differences ($F_{1,32}=0{\cdot}43$).

## 4. Discussion

These data suggest that several of the contrasts made were highly influenced by size, but that this failed to account for all differences between species. Few comparisons

between the sexes were significant, but we suspect this is more a reflection of low sample sizes than a true result.

The data further suggest that *E.* (*M.*) *confrator* is possibly a more useful predator than the other species, at least from the standpoint of the number of aphids killed per predator during development. Efforts to improve the biological control of *L. erysimi* using syrphids should concentrate on this species, to determine whether other aspects of its biology and ecology are also favourable for its use in biocontrol.

Opinion is divided as to the utility of syrphids as biocontrol agents of aphids. Work done 20 years ago seemed to write them off due to their lack of synchrony with their prey, and their inability to restrain aphid numbers below an economic threshold. More recent work (Chambers and Adams 1986) suggests that this view may be premature, and that particularly in cereals and in greenhouses but also elsewhere they may play a major role. It is certain that many previous studies relied on inadequate sampling methods: syrphids larvae are largely nocturnal feeders, moving off the plant during the day. Daytime sampling procedures adequate for aphids and other predators may fail completely to provide even roughly accurate density estimates.

Efforts to model the effect of aphid-specific predators have been hampered in the case of syrphids by a lack of appropriate data (Raworth 1984). A complete survey of

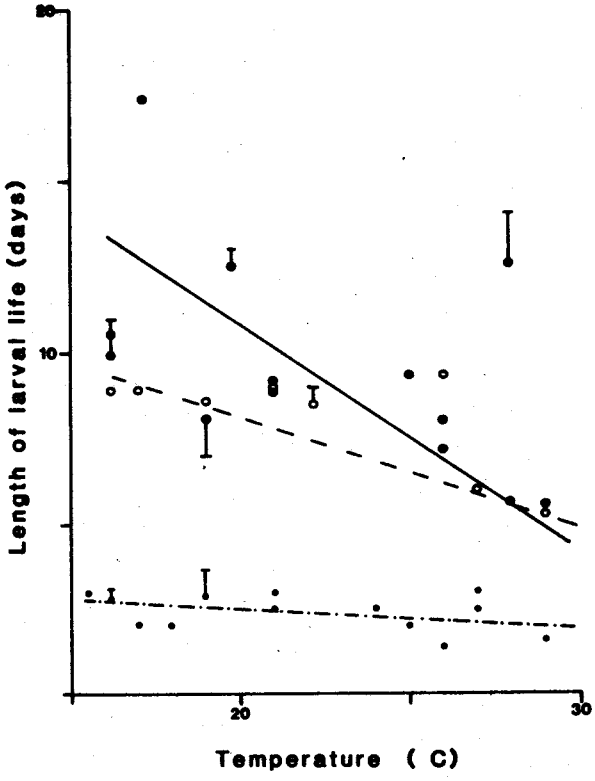


Figure 3. Literature data on longevity of the egg, larva and puparium of *I. scutellaris*. Data from Lal and Lal Gupta (1953), Lal and Haque (1955), Patel and Patel (1969), Mathur and Sharma (1973), Patnaik and Bhagat (1976), Gafarov (1979), Alfiler and Calilung (1980) and Agarwala and Saha (1986). (●), Larvae; (○), puparia; (o), eggs.

the syrphid literature (Gilbert F S, unpublished results) actually reveals significant amounts of usable data. As an example, we consider just one of our 6 species, *I. scutellaris*. Figure 3 plots literature data on longevity of the stages as a function of temperature (uncontrolled in some studies, such as this one). There is a significant negative relationship, as expected (e.g. larval longevity, $r = -0{\cdot}53$, $n = 12$, $P < 0{\cdot}05$). The data reiterate Benestad's (1970) conclusion that fluctuating temperatures (such as in this study) have very nearly the same effect on longevity as a constant one equivalent to the mean: therefore laboratory data from constant temperatures may well be sufficiently realistic to use in modelling. Such data as ours are not unusual in the literature, and could prove valuable for use in population models of aphid dynamics (models which of course will require validation from field studies).

Out of the 6 syrphids studied, *E. (M.) confrator* shows the greatest predatory potential, at least from this laboratory study of voracity; the other 5 species are more or less equivalent in these terms. Future work will address the impact of syrphid predator on *L. erysimi* in the field, which we suspect to be substantial, to test whether this prediction is in fact true. We believe that syrphid predators show great promise as elements in the biocontrol of *L. erysimi* in cruciferous crops.

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**References**

Agarwala B K, Ghosh D and Raychaudhuri D N 1981 Life history of two aphidophagous syrphid species (Diptera: Syrphidae) in West Bengal, India; *Pranikee* **3** 15–21

Agarwala B K and Saha J L 1986 Larval voracity, development and relative abundance of predators of *Aphis gossypii* on cotton in India; in *Ecology of Aphidophaga* II (ed.) I Hodek (Prague: Academia) pp 339–344

Alfiler A R R and Calilung V J 1980 The life history and voracity of the syrphid predator *Ischiodon scutellaris* sic (F) (Diptera, Syrphidae); *Philip. Entomol.* **4** 105–117

Bakhetia D R C 1983 Losses in rape-seed/mustard due to *Lipaphis erysimi* (Kalt.) in India: a literature study; *Proc. 6th Int. Rapeseed Conf.*, Paris, pp 1142–1147

Benestad E 1970 Laboratory experiments on the biology of *Syrphus corollae* (Fabr.) (Dipt., Syrphidae); *Nor. Entomol. Tidsskr.* **17** 77–85

Bhatia H L and Shaffi E M 1932 Life histories of some Indian Syrphidae; *Indian J. Agric. Sci.* **2** 543–569

Chambers R J and Adams T H L 1986 Quantification of the impact of hoverflies on cereal aphids in winter wheat-analysis of field populations; *J. Appl. Ecol.* **23** 895–904

Gafarov S 1979 Syrphid flies—components of the cotton agrobiocoenosis in Tadzhikistan; *Izv. Akad. Nauk Tadzh. SSR Otd. Biol. Nauk* **3** 41–45

Ghosh M R and Mitra A 1983 Incidence pattern and population composition of *Lipaphis erysimi* (Kaltenbach) on mustard and radish; in *The Aphids* (ed.) B K Behura (Bhubaneswar: The Zoological Society of Orissa) pp 43–51

Lal L and Haque E 1955 Effect of nutrition under controlled conditions of temperature and humidity on longevity and fecundity of *Sphaerophoria scutellaris* (Fabr.) (Syrphidae, Diptera)—efficacy of its maggots as aphid predators; *Indian J. Entomol.* **17** 317–327

Lal L and Lal Gupta S B 1953 Morphology of the immature stages of *Sphaerophoria scutellaris* (Fabr.) (Syrphidae: Diptera) with notes on its biology; *Indian J. Entomol.* **15** 207–218

Mathur T K and Sharma J C 1973 Studies on the predaceous behaviour and bionomics of *Xanthogramma scutellare* Fabr. and *Sphaerophoria* sp. (Diptera, Syrphidae); *Univ. Udaipur Res. J.* **11** 52–53

Patel J R and Patel H K 1969 The bionomics of the syrphid fly, *Xanthogramma scutellare* Fab. (Syrphidae, Diptera); *Madras Agric. J.* **56** 516–522

Patnaik N C and Bhagat K C 1976 The syrphid fauna of Puri District (Orissa) and bio-ecology of *Ischiodon scutellaris* Fabr. and *Eumerus* sp. nr *albifrons* Walk.; *Prakruti—Utkal Univ. J. Sci.* **13** 45–50

Rahman K A 1940 Important insect predators of India; *Proc. Indian Acad. Sci.* **B12** 67–74

Rao V P 1969 *Survey for natural enemies of aphids of India*, CIBC, PL 480 Project, Final Technical Report, p 93

Raworth D 1984 Population dynamics of the cabbage aphid, *Brevicoryne brassicae* (Homoptera, Aphididae) at Vancouver, British Columbia. V. A simulation model; *Can. Entomol.* **116** 895–911

Roy P and Bose S K 1977 Bionomics of aphidophagous syrphid flies; *Indian J. Entomol.* **39** 165–174

Sokal R R and Rohlf F 1969 *Biometry* (San Francisco: Freeman)