



Growth rates indices as a tool in the biosystematics of four species of *Rhynocoris Kolenati* (Insecta: Hemiptera: Reduviidae: Harpactorinae)

V Jeba Singh^{2*}, Dunston P Ambrose¹

¹ Entomology Research Unit, St. Xavier's College (Autonomous), Palayamkottai, Tamil Nadu, India

² Sri Ram Nallamani Yadava, College of Arts and Sciences, Tenkasi, Tamil Nadu, India

Abstract

Growth rate indices of postembryonic developmental morphometry of head, cephalic appendages, thorax, thoracic appendages and abdomen of life stages of four *Rhynocoris* species viz., *R. fuscipes* (F.), *R. kumarii* Ambrose and Livingstone, *R. longifrons* (Stål) and *R. marginatus* (F.) were analysed. The growth rate between the life stages were taken as two indices to the generic and specific diagnostic characters and interspecific affinity. Twenty four comparative growth rates between various parts of the chosen assassin bugs resulted from the growth rates of life stages were taken into consideration. The results revealed generic and specific diagnostic characters and interspecific affinity.

Moreover, the analysis revealed the highest affinity between *R. kumarii* and *R. marginatus* and the least affinity between *R. fuscipes* and *R. longifrons* through exactly similar value analysis. It was further confirmed by almost similar value analysis and the dendrogram analysis by the nodes of grouped characters. The analysis of growth rates indices also revealed that *R. longifrons* has the highest unique characters. The above findings suggest that growth indices could be used as an intrageneric and interspecific biosystematics tool.

Keywords: *Rhynocoris*, assassin bugs, biological control agents, postembryonic development, morphometry, biosystematics tool

Introduction

Information regarding post-embryonic developmental characteristics of insects has been used as a tool in the biosystematics of insects (Daly, 1985 and Rohlf, 1990) [10, 29]. Ambrose and Ambrose (2004) [2] studied the Growth indices of various parts of life stages (I nymphal instar to adult) of thirty species of reduviids belonging to three major sub-families namely Harpactorinae, Reduviinae and Peiratinae to explore the possibilities of utilising these values as a tool in the biosystematics of Reduviidae. An attempt has been made to understand the feasibility of utilising the postembryonic developmental growth rates indices of four species of *Rhynocoris* viz., *Rhynocoris fuscipes* (Fabricius), *Rhynocoris kumarii* Ambrose and Livingstone, *Rhynocoris longifrons* (Stål) and *Rhynocoris marginatus* (Fabricius) in the biosystematics of Reduviidae. Since reduviids are natural enemies of several insect pests, present study helps accurate identification of these potential biological control agents for their effective utilization in the Integrated Pest Management.

According to Dyar's rule (Dyar, 1890) [11] the larval head width in successive instar following a regular geometric progression, be linear or isometric (Ghent, 1956) [15]. Since this rule was first reported by Brooks (1986) [8] it is also called as Brooks-Dyar rule (Hutchinson and Tongring, 1984) [20]. Growth can be isometric or allometric. Allometry was reported in insects. McCreadia and Colbo (1990) [24] reported allometry in the last larval instar of *Simulium truncatum* (Lundstrom) and *S. rostratum* (Lundstrom) (Diptera: Simuliidae). It is a practical guide (Taylor, 1931: Gould, 1966 and MaCkay, 1978) [31, 16, 23] but not applicable to all group of insects (Gaines and Campbell, 1935 and

Miles, 1931) [14, 25]. Growth rates varies individually (Bliss and Beard, 1954) [7] and among sexes (Atchley, 1971; Atchley and Martin, 1971) [4, 5] and changes in growth rates can be visualized by slope of growth curves (Gaines and Campbell, 1935; Fontaine and Pilon, 1979; Cuffney and Minshall, 1981) [14, 13, 9]. Sometimes no growth is observed in one or more instar (Ghent, 1956 and Miles, 1931) [15, 25]. Growth curves were also studied among the progeny of cross between the laboratory reared and field collected individuals (Hoxie and Wellso, 1974 and Kishi, 1971) [19, 21], individuals reared on different food in the laboratory (Beck, 1950) [6], individuals reared at different temperature in the laboratory (Guppy, 1969; Hensleigh and Atchley, 1977 and kishi, 1971) [17, 18, 21] and of individuals at different seasons (Peterson and Hacussler, 1928 and Mizell and Nebeker, 1979) [20, 26]. Ratios calculated from morphometric analysis were further analysed to determine if allometry is existed. Eddleman (1967) [12] reported the morphological and biometrical differentiation and growth rates curves and ratios of the larval instar of mosquitoes *Orthopodomyia alba* and *O. signifera* were useful for instar recognition.

Wignall and Taylor (2008) [32] studied the growth rate in an araneophagic assassin bug, *Stenolemus bituberus* Stål and reported that the growth rate between instars is fairly constant, with the exception of two major transitions the 1st and 2nd in stars and the 5th instar and adult. The control of body size is not so much a control of growth but a control of when to stop growing (Nijhout, 2003) [27].

Rukmani (1992) [30] expanded the work of Ambrose (1987) [1]. She used morphometrical, biological growth, linear regression coefficients of postembryonic developmental characteristics and behavioural tools to demarcate and

distinguish three subfamilies-Harpactorinae, Reduviinae and Peiratinae. She included 36 morphometric indices comparing different parts of 27 species of reduviids belonging to 14 genera and concluded that these indices are useful at the subfamily level. Her further formulation of growth indices using growth rates of 25 different parts of 24 species belonging to 13 genera suggested that they are highly useful in the demarcation of species, genera and to a certain extent the subfamilies and to trace their affinity.

Ambrose and Ambrose (2004) [2] growth indices of various parts of life stages (I nymphal instars to adult) of thirty species of reduviids belonging to three major subfamilies, namely, Harpactorinae, Reduviinae and Peiratinae were analysed to explore the possibilities of utilising these values as a tool in the biosystematics.

Ambrose and Ambrose (2009) [3] analyses of 36 morphometric indices belonging to 27 species, 14 genera and 3 subfamilies viz., Harpactorinae, Peiratinae and Reduviinae by direct observation as well as unweighted pair group method using arithmetic mean (UPGMA) incorporating Euclidean distances, Nei and Li's genetic distance coefficient and Jaccard's coefficient reveals diagnostic intra as well as inter subfamilial and generic affinities. Moreover, it gives an insight into the placement of genera in the existing divisions (tribes) of subfamilies and their phylogenetic relationship. Further, it clearly suggests a two diversified lines of evolution of Peiratinae and Reduviinae from Harpactorinae than the earlier suggested straight line evolution of these two subfamilies from Harpactorinae.

Material and Methods

The growth indices of post embryonic development of life stages (I nymphal instar to adult) of four *Rhynocoris* species namely, *R. fuscipes*, *R. kumarii*, *R. longifrons* and *R. marginatus* were analysed.

From the morphometric data of the life stages (I nymphal instar to the adult) of above said species, the growth index was calculated for five stages viz., I to II, II to III, III to IV, IV to V nymphal instar and V nymphal instar to adult (average of males and females) by dividing the morphometric measurement of the succeeding stage by the preceding stage. After calculating the growth indices for those five stages, an average growth index for the species was calculated since it was found difficult to compare the growth index of five stages for four *Rhynocoris* species. Moreover, individual growth indices for different life stages also led to confusion. These values were computed and analysed. Affinity was calculated by identifying exact values or relatively closer values. The following growth rates indices were calculated.

1. Anteocular length (AOL), 2. Postocular length (POL), 3. Width between eyes (WBE), 4. Diameter of eye (DE), 5. Head length (HL), 6. Head width (HW), 7. Scape length (SL), 8. Pedicel length (PL), 9. First flagellar Segment length (F₁L), 10. Second flagellar Segment length (F₂L), 11. Entire Antennal length (EAL), 12. Basal rostral segment length (BRL), 13. Medial rostral segment length (MRL), 14. Terminal rostral segment length (MRL), 15. Entire rostral length (ERL), 16. Prothorax length (PTL), 17. Prothorax width (PTW), 18. Fore tibial length (FTL), 19. Mid tibial length (MTL), 20. Hind tibial length (HTL), 21. Wing length (WL), 22. Wing width (WW), 23. Abdomen length (AL) and 24. Abdomen width (AW).

Cluster analysis was made using the software in A MultiVariate Statistical Package for Windows, ver. 3.1. A dendrogram was constructed with Unweighted Pair Group Method with Arithmetic Mean (UPGMA) clustering and the similarity matrix index was calculated by the percent similarity coefficient (Kovach, 2007) [22].

Results

1. Anteocular length (AOL)

Exactly Similar value: Growth rates of III to IV nymphal instar in *R. kumarii* and *R. marginatus* are exactly similar (1.29).

Almost Similar value: Growth rates of I to II nymphal instar (1.32 and 1.36); II to III nymphal instar in *R. kumarii* and *R. longifrons* (1.44 and 1.42); IV to V nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.41, 1.42 and 1.39); V nymphal instar to adult male in *R. fuscipes* and *R. marginatus* (1.09 and 1.04) and V nymphal instar to adult female in *R. kumarii* and *R. marginatus* (1.10 and 1.04) are almost similar.

2. Postocular length (POL)

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes* and *R. marginatus* (1.47 and 1.46); III to IV nymphal instar in *R. longifrons* and *R. marginatus* (1.26 and 1.28); IV to V nymphal instar in *R. fuscipes* and *R. marginatus* (1.25 and 1.21) and V nymphal instar to adult male in *R. kumarii* and *R. longifrons* (1.07 and 1.02) are almost similar.

3. Width between eyes (WBE)

Almost Similar value: Growth rates of I to II nymphal instar (1.27 and 1.25); II to III nymphal instar in *R. fuscipes* and *R. marginatus* (1.16 and 1.18); III to IV nymphal instar in *R. kumarii* and *R. longifrons* (1.23 and 1.21); IV to V nymphal instar in *R. kumarii*, *R. longifrons* and *R. marginatus* (1.11, 1.14 and 1.16); V nymphal instar to adult male in *R. kumarii* and *R. longifrons* (1.17 and 1.15) and V nymphal instar to adult female in *R. fuscipes* and *R. marginatus* (1.04 and 1.02) are almost similar.

4. Diameter of eye (DE)

Exactly Similar value: Growth rates of III to IV nymphal instar in *R. fuscipes* and *R. kumarii* are exactly similar (1.18).

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes* and *R. kumarii* (1.38 and 1.32); II to III nymphal instar in *R. kumarii* and *R. marginatus* (1.35 and 1.39); III to IV nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.18, 1.18 and 1.19); IV to V nymphal instar in *R. fuscipes* and *R. kumarii* (1.29 and 1.35); V nymphal instar to adult male in *R. fuscipes* and *R. marginatus* (1.14 and 1.19) and V nymphal instar to adult female in *R. longifrons* and *R. marginatus* (1.27 and 1.21) are almost similar.

5. Head length (HL)

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes*, *R. longifrons* and *R. marginatus* (1.49, 1.48 and 1.50); II to III nymphal instar in *R. fuscipes* and *R. kumarii* (1.51 and 1.46); III to IV nymphal instar in *R. kumarii* and *R. longifrons* (1.32 and 1.35); IV to V nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.31, 1.29 and 1.28); V nymphal instar to adult male in *R.*

fuscipes and *R. kumarii* (1.06 and 1.02) and *R. longifrons* and *R. marginatus* (1.19 and 1.14) and V nymphal instar to adult female in *R. kumarii* and *R. marginatus* (1.11 and 1.15) are almost similar.

6. Head width (HW)

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes* and *R. marginatus* (1.33 and 1.38); II to III nymphal instar in *R. fuscipes* and *R. longifrons* (1.23 and 1.20) and *R. kumarii* and *R. marginatus* (1.34 and 1.30); III to IV nymphal instar in *R. longifrons* and *R. marginatus* (1.28 and 1.25); V nymphal instar to adult male in *R. fuscipes* and *R. marginatus* (1.11 and 1.16) and V nymphal instar to adult female in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.11, 1.14 and 1.13) are almost similar.

7. Scape length (SL)

Exactly Similar value: Growth rates of IV to V nymphal instar in *R. kumarii* and *R. marginatus* are exactly similar (1.22).

Almost Similar value: Growth rates of I to II nymphal instar in *R. kumarii* and *R. longifrons* (1.30 and 1.31); II to III nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.30, 1.29 and 1.27); III to IV nymphal instar in *R. longifrons* and *R. marginatus* (1.17 and 1.22); V nymphal instar to adult male in *R. fuscipes*, *R. kumarii* and *R. longifrons* (1.07, 1.09 and 1.02) and V nymphal instar to adult female in *R. kumarii*, *R. longifrons* and *R. marginatus* (1.25, 1.20 and 1.21) are almost similar.

8. Pedicel length (PL)

Exactly Similar value: Growth rates of I to II nymphal instar in *R. longifrons* and *R. marginatus* are exactly similar (1.50).

Almost Similar value: Growth rates of II to III nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.33, 1.36 and 1.32); III to IV nymphal instar in *R. fuscipes* and *R. marginatus* (1.25 and 1.28); IV to V nymphal instar in *R. kumarii* and *R. marginatus* (1.22 and 1.24); V nymphal instar to adult male in *R. fuscipes* and *R. kumarii* (1.29 and 1.26) and V nymphal instar to adult female in *R. kumarii* and *R. marginatus* (1.26 and 1.28) are almost similar.

9. First flagellar Segment length (F₁L)

Almost Similar value: Growth rates of I to II nymphal instar in *R. kumarii* and *R. longifrons* (1.43 and 1.40); II to III nymphal instar in *R. kumarii* and *R. marginatus* (1.64 and 1.59); III to IV nymphal instar in *R. fuscipes* and *R. longifrons* (1.56 and 1.60) and *R. kumarii* and *R. marginatus* (1.52 and 1.51) and V nymphal instar to adult female in *R. longifrons* and *R. marginatus* (1.21 and 1.20) are almost similar.

10. Second flagellar Segment length (F₂L)

Exactly Similar value: Growth rates of I to II nymphal instar in *R. fuscipes* and *R. kumarii* (1.23) and III to IV nymphal instar in *R. longifrons* and *R. marginatus* (1.22) are exactly similar.

Almost Similar value: Growth rates of III to IV nymphal instar in *R. kumarii*, *R. longifrons* and *R. marginatus* (1.25, 1.22 and 1.22); IV to V nymphal instar in *R. kumarii* and *R. longifrons* (1.18 and 1.16); V nymphal instar to adult male in *R. kumarii* and *R. marginatus* (1.13 and 1.11) and V nymphal instar to adult female in *R. fuscipes* and *R. kumarii*

(1.16 and 1.11) and *R. longifrons* and *R. marginatus* (1.08 and 1.07) are almost similar.

11. Entire Antennal length (EAL)

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes* and *R. longifrons* (1.34 and 1.36); II to III nymphal instar in *R. kumarii* and *R. marginatus* (1.33 and 1.29); III to IV nymphal instar in *R. fuscipes*, *R. longifrons* and *R. marginatus* (1.28, 1.27 and 1.26); IV to V nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.20, 1.24 and 1.27); V nymphal instar to adult male in *R. fuscipes* and *R. longifrons* (1.24 and 1.22) and *R. kumarii* and *R. marginatus* (1.16 and 1.18) and V nymphal instar to adult female in *R. fuscipes* and *R. kumarii* (1.21 and 1.23) and *R. longifrons* and *R. marginatus* (1.19 and 1.18) are almost similar.

12. Basal rostral segment length (BRL)

Almost Similar value: Growth rates of I to II nymphal instar in *R. kumarii* and *R. marginatus* (1.28 and 1.30); II to III nymphal instar (1.59 and 1.54); III to IV nymphal instar (1.38 and 1.39) and IV to V nymphal instar in *R. kumarii* and *R. marginatus* (1.32 and 1.35); V nymphal instar to adult male in *R. fuscipes*, *R. kumarii* and *R. longifrons* (1.22, 1.25 and 1.28) and V nymphal instar to adult female in *R. kumarii* and *R. marginatus* (1.31 and 1.32) are almost similar.

13. Medial rostral segment length (MRL)

Exactly Similar value: Growth rates of I to II nymphal instar in *R. fuscipes* and *R. marginatus* are exactly similar (1.33).

Almost Similar value: Growth rates of I to II nymphal instar in *R. kumarii* and *R. longifrons* (1.44 and 1.40); II to III nymphal instar (1.29 and 1.23) and III to IV nymphal instar in *R. fuscipes* and *R. kumarii* (1.31 and 1.30); IV to V nymphal instar (1.21 and 1.26) and V nymphal instar to adult male in *R. kumarii* and *R. marginatus* (1.16 and 1.19) are almost similar.

14. Terminal rostral segment length (TRL)

Exactly Similar value: Growth rates of III to IV nymphal instar in *R. fuscipes* and *R. kumarii* are exactly similar (1.07).

Almost Similar value: Growth rates of II to III nymphal instar in *R. fuscipes* and *R. kumarii* (1.21 and 1.25); III to IV nymphal instar in *R. fuscipes*, *R. kumarii* and *R. longifrons* (1.07, 1.07 and 1.09) and V nymphal instar to adult female in *R. kumarii* and *R. longifrons* (1.11 and 1.13) are almost similar.

15. Entire rostral length (ERL)

Exactly Similar value: Growth rates of I to II nymphal instar in *R. kumarii* and *R. marginatus* are exactly similar (1.37).

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.36, 1.37 and 1.37); II to III nymphal instar in *R. longifrons* and *R. marginatus* (1.45 and 1.40); III to IV nymphal instar (1.29 and 1.31) and IV to V nymphal instar in *R. kumarii* and *R. marginatus* (1.29 and 1.27); V nymphal instar to adult male in *R. fuscipes* and *R. marginatus* (1.22 and 1.21) and *R. kumarii* and *R. longifrons* (1.19 and 1.17) and V nymphal instar to adult female in *R. fuscipes* and *R. marginatus* (1.41 and 1.36) and *R. kumarii* and *R. longifrons* (1.23 and 1.29) are almost similar.

16. Prothorax length (PTL)

Exactly Similar value: Growth rates of I to II nymphal instar in *R. longifrons* and *R. marginatus* are exactly similar (1.42).

Almost Similar value: Growth rates of I to II nymphal instar in *R. kumarii*, *R. longifrons* and *R. marginatus* (1.44, 1.42 and 1.42); II to III nymphal instar in *R. fuscipes* and *R. longifrons* (1.27 and 1.25) and *R. kumarii* and *R. marginatus* (1.54 and 1.52); III to IV nymphal instar in *R. fuscipes*, *R. longifrons* and *R. marginatus* (1.45, 1.46 and 1.47) and IV to V nymphal instar in *R. fuscipes* and *R. marginatus* (1.44 and 1.39) are almost similar.

17. Prothorax width (PTW)

Exactly Similar value: Growth rates of V nymphal instar to adult male in *R. kumarii* and *R. marginatus* are exactly similar (2.41).

Almost Similar value: Growth rates of I to II nymphal instar in *R. kumarii* and *R. longifrons* (1.25 and 1.30); II to III nymphal instar (1.32 and 1.33) and III to IV nymphal instar in *R. longifrons* and *R. marginatus* (1.46 and 1.44); IV to V nymphal instar (1.43 and 1.46) and V nymphal instar to adult female in *R. kumarii* and *R. marginatus* (2.47 and 2.54) are almost similar.

18. Foretibial length (FTL)

Exactly Similar value: Growth rates of III to IV nymphal instar in *R. fuscipes* and *R. longifrons* (1.25) and *R. kumarii* and *R. marginatus* (1.34) are exactly similar.

Almost Similar value: Growth rates of I to II nymphal instar (1.32, 1.34 and 1.37); II to III nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.31, 1.34 and 1.33); IV to V nymphal instar in *R. fuscipes* and *R. longifrons* (1.06 and 1.05) and *R. kumarii* and *R. marginatus* (1.29 and 1.31) and V nymphal instar to adult male in *R. kumarii* and *R. longifrons* (1.09 and 1.10) are almost similar.

19. Midtibial length (MTL)

Exactly Similar value: Growth rates of V nymphal instar to adult female in *R. kumarii* and *R. marginatus* are exactly similar (1.18).

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes* and *R. kumarii* (1.31 and 1.30); II to III nymphal instar (1.35 and 1.38); III to IV nymphal instar (1.33 and 1.34); IV to V nymphal instar in *R. kumarii* and *R. marginatus* (1.29 and 1.28) and V nymphal instar to adult male in *R. kumarii*, *R. longifrons* and *R. marginatus* (1.10, 1.07 and 1.14) are almost similar.

20. Hind tibial length (HTL)

Exactly Similar value: Growth rates of IV to V nymphal instar in *R. kumarii* and *R. marginatus* (1.27) and V nymphal instar to adult female in *R. fuscipes* and *R. kumarii* are exactly similar (1.22).

Almost Similar value: Growth rates of I to II nymphal instar in *R. fuscipes*, *R. kumarii* and *R. longifrons* (1.34, 1.35 and 1.31); II to III nymphal instar in *R. fuscipes* and *R. longifrons* (1.29 and 1.30) and *R. kumarii* and *R. marginatus*

(1.36 and 1.33); III to IV nymphal instar in *R. kumarii*, *R. longifrons* and *R. marginatus* (1.39, 1.41 and 1.36); IV to V nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.30, 1.27 and 1.27); V nymphal instar to adult male in *R. fuscipes*, *R. kumarii* and *R. longifrons* (1.17, 1.13 and 1.14) and V nymphal instar to adult female in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.22, 1.22 and 1.25) are almost similar.

21. Wing length (WL)

Almost Similar value: Growth rates of V nymphal instar to adult female in *R. fuscipes* and *R. kumarii* (3.21 and 3.26) are almost similar.

22. Wing width (WW)

Growth rates of *R. fuscipes*, *R. kumarii*, *R. longifrons* and *R. marginatus* are not similar.

23. Abdomen length (AL)

Exactly Similar value: Growth rates of III to IV nymphal instar in *R. longifrons* and *R. marginatus* (1.24); V nymphal instar to adult male in *R. kumarii* and *R. marginatus* are exactly similar (1.27).

Almost Similar value: Growth rates of II to III nymphal instar in *R. kumarii* and *R. marginatus* (1.57 and 1.56); III to IV nymphal instar in *R. fuscipes*, *R. longifrons* and *R. marginatus* (1.25, 1.24 and 1.24); IV to V nymphal instar in *R. fuscipes* and *R. longifrons* (1.05 and 1.02) V nymphal instar to adult male in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.30, 1.27 and 1.27) and V nymphal instar to adult female in *R. kumarii* and *R. marginatus* (1.56 and 1.57) are almost similar.

24. Abdomen width (AW)

Exactly Similar value: Growth rates of IV to V nymphal instar in *R. fuscipes* and *R. marginatus* are exactly similar (1.44).

Almost Similar value: Growth rates of IV to V nymphal instar in *R. fuscipes*, *R. kumarii* and *R. marginatus* (1.44, 1.42 and 1.44); V nymphal instar to adult male (1.64 and 1.65); V nymphal instar to adult female in *R. kumarii* and *R. marginatus* (1.97 and 1.96) and *R. fuscipes* and *R. longifrons* (1.32 and 1.35) are almost similar.

Cluster Analysis

The growth rates indices of postembryonic development among the life stages I to II, II to III, III to IV, IV to V nymphal instar and V nymphal instar to adult of four *Rhynocoris* species were used to construct dendrograms by UPGMA clustering method. The analysis revealed phylogenetic relationship among the four *Rhynocoris* species (Fig 1 to 6).

I to II nymphal instar

I to II nymphal instar has the highest similarity in EAL and MTL (99.53%) followed in ERL and FTL (98.67%), POL and HL (97.59%), F2L and PTW (96.72%), BRL and TRL (94.63%) and AL and AW (90.98%) (Fig 1).

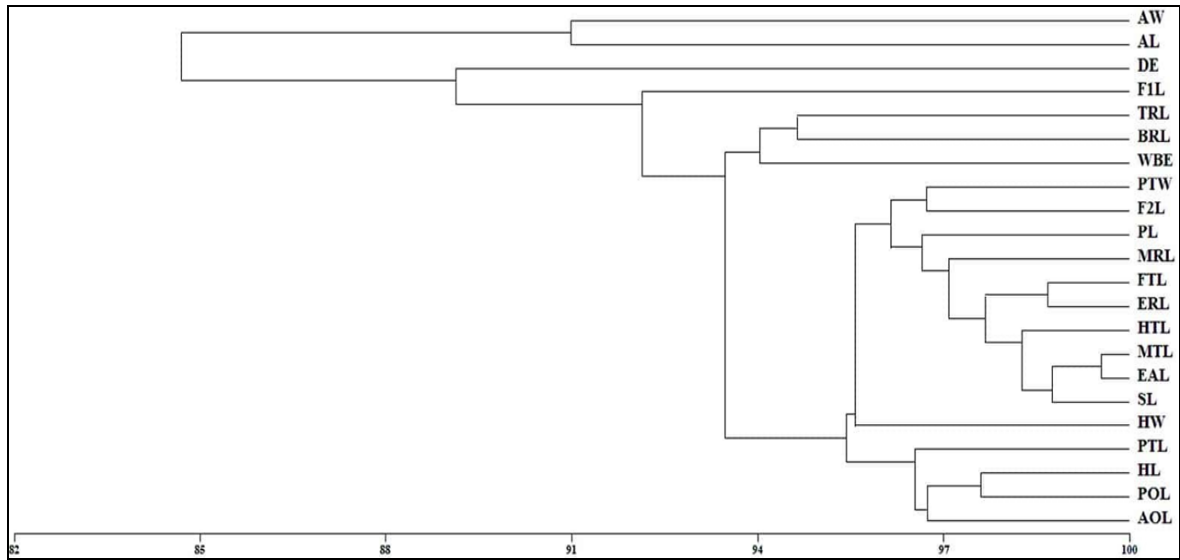


Fig 1: Phylogenetic affinity between I to II nymphal instar among four *Rhynocoris* species based on growth rate indices analysed by UPGMA clustering method (percent similarity coefficient)

II to III nymphal instar

II-III nymphal instar has the highest similarity in DE and MTL (99.61%) followed in HW and EAL (99.00%), FTL

and HTL (98.68%), AOL and HL (98.59%), POL and PTW (98.29%), F1L and PTL (97.63%), AL and AW (97.00%) and WBE and F2L (96.57%) (Fig 2).

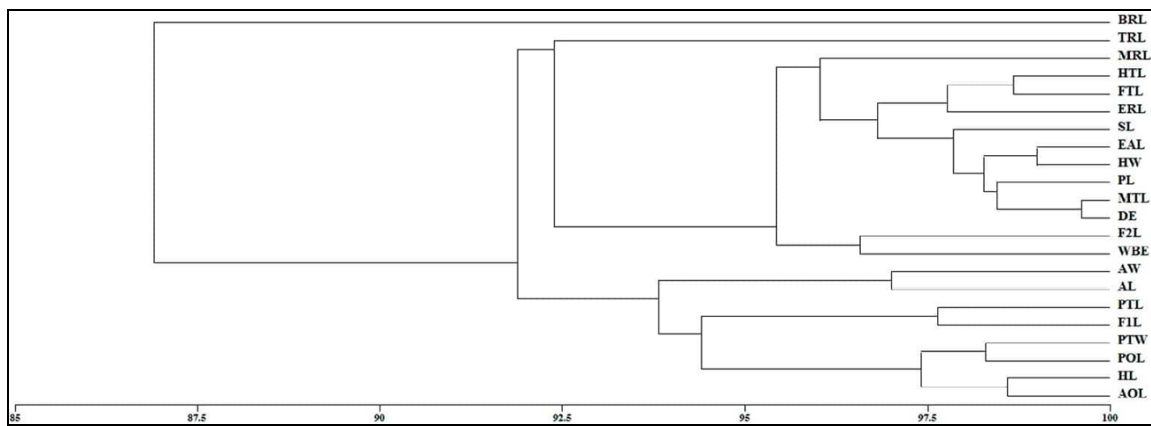


Fig 2: Phylogenetic affinity between II to III nymphal instar among four *Rhynocoris* species based on growth rate indices analysed by UPGMA clustering method (percent similarity coefficient)

III to IV nymphal instar

III to IV nymphal instar has the highest similarity in AOL and MTL (99.06%) followed in PL and EAL (98.61%), DE

and HW (98.25%), WBE and F2L (98.23%), F1L and PTL (97.44%), POL and AW (96.80%) and WL and WW (92.18%) (Fig 3).

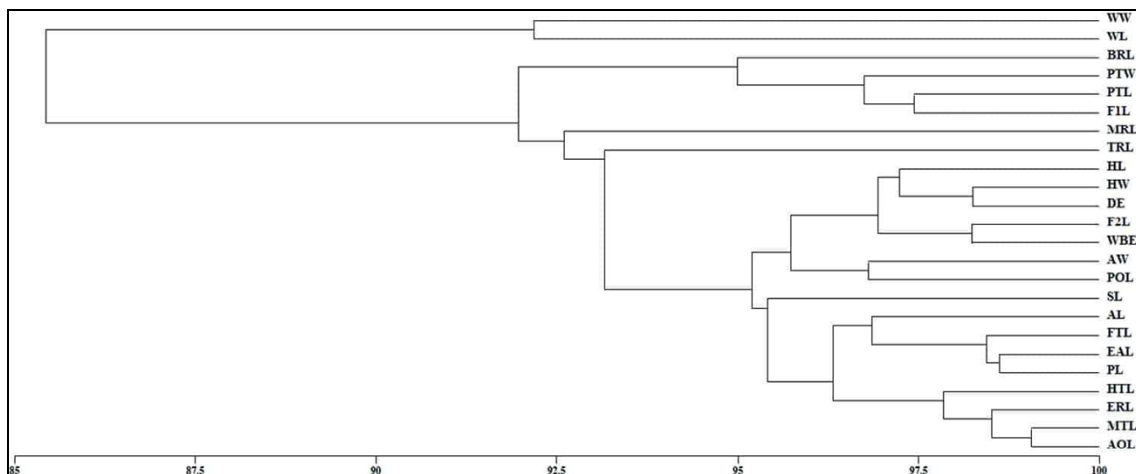


Fig 3: Phylogenetic affinity between III to IV nymphal instar among four *Rhynocoris* species based on growth rate indices analysed by UPGMA clustering method (percent similarity coefficient)

IV to V nymphal instar

IV to V nymphal instar has the highest similarity in EAL and ERL (99.47%) followed in PL and MRL (99.45%), HL

and HTL (99.28%), BRL and FTL (98.02%), HW and F2L (97.75%), AOL and PTL (97.58%), PTW and AW (97.13%) and F1L and WW (94.01%) (Fig 4).

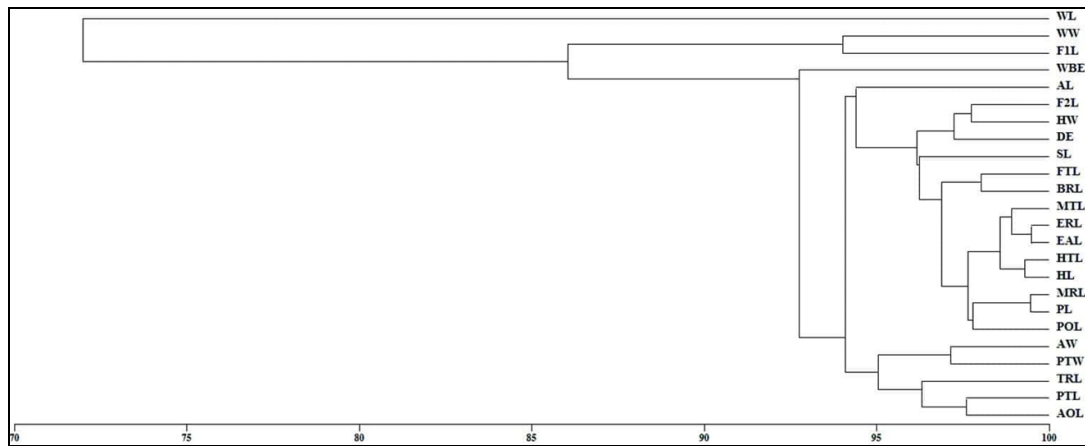


Fig 4: Phylogenetic affinity between IV to V nymphal instar among four *Rhynocoris* species based on growth rate indices analysed by UPGMA clustering method (percent similarity coefficient)

V nymphal instar to adult male

V nymphal instar to adult male has the highest similarity in POL and SL (98.73%) followed in EAL and ERL (98.64%),

MRL and MTL (98.46%), HL and HW (98.21%), PTL and PTW (97.08%) and WL and WW (89.40%) (Fig 5).

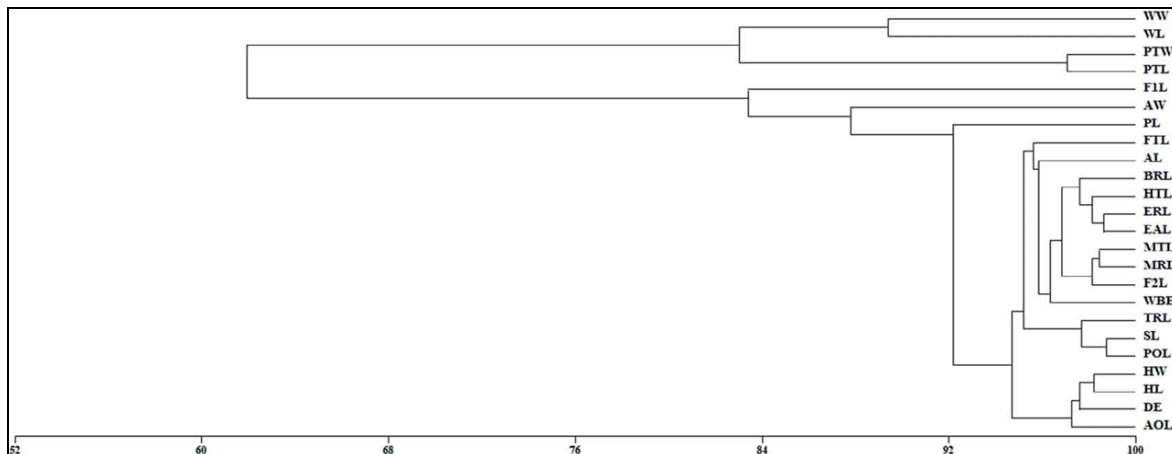


Fig 5: Phylogenetic affinity between V nymphal instar to adult male among four *Rhynocoris* species based on growth rate indices analysed by UPGMA clustering method (percent similarity coefficient)

V nymphal instar to adult female

V nymphal instar to adult female has the highest similarity in SL and EAL (98.96%) followed in MRL and ERL

(98.13%), AOL and HL (97.93%), DE and HW (97.74%), FIL and MTL (97.14%), PTL and PTW (94.46%), AL and AW (88.88%) and WL and WW (87.59%) (Fig 6).

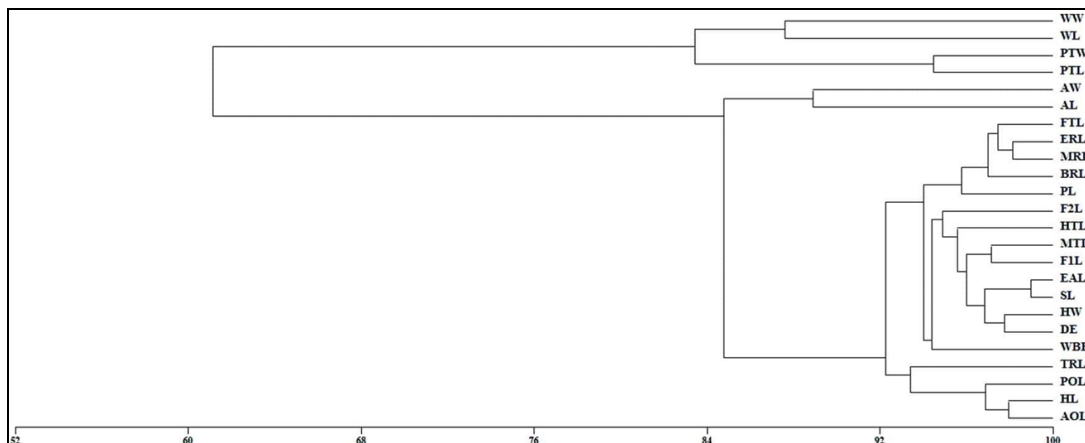


Fig 6: Phylogenetic affinity between V nymphal instar to adult female among four *Rhynocoris* species based on growth rate indices analysed by UPGMA clustering method (percent similarity coefficient)

Discussion

Exactly similar value

1. *R. fuscipes* and *R. kumarii*

R. fuscipes and *R. kumarii* have exactly similar values of I to II nymphal instar in second flagellar segment length; III to IV nymphal instar in diameter of eye and terminal rostral segment length and V nymphal instar to adult female in hind tibial length.

2. *R. fuscipes* and *R. longifrons*

R. fuscipes and *R. longifrons* have exactly similar values of III to IV nymphal instar in foretibial length.

3. *R. fuscipes* and *R. marginatus*

R. fuscipes and *R. marginatus* have exactly similar values of I to II nymphal instar in medial rostral segment length and IV to V nymphal instar in abdomen width.

4. *R. kumarii* and *R. marginatus*

R. kumarii and *R. marginatus* have exactly similar values of I to II nymphal instar in entire rostral length and prothorax length; III to IV nymphal instar in anteocular length and fore-tibial length; IV to V nymphal instar in scape length and hind tibial length; V nymphal instar to adult male in prothorax width and abdomen length and V nymphal instar to adult female in midtibial length.

5. *R. longifrons* and *R. marginatus*

R. longifrons and *R. marginatus* have exactly similar values of I to II nymphal instar in pedicel length and prothorax length and III to IV nymphal instar in second flagellar segment length and abdomen length.

Almost Similar Value

1. *R. fuscipes* and *R. kumarii*

R. fuscipes and *R. kumarii* have almost similar values of I to II nymphal instar in diameter of eye and midtibial length; II to III nymphal instar in head length and medial rostral segment length and terminal rostral segment length; III to IV nymphal instar in medial rostral segment length; IV to V nymphal instar in diameter of eye; V nymphal instar to adult male in head length and pedicel length and V nymphal instar to adult female in second flagellar segment length, entire antennal length and wing length.

2. *R. fuscipes* and *R. longifrons*

R. fuscipes and *R. longifrons* have almost similar values of I to II nymphal instar in entire antennal length; II to III nymphal instar in head width, prothorax length and hind tibial length; III to IV nymphal instar in first flagellar segment length; IV to V nymphal instar in foretibial length and abdomen length; V nymphal instar to adult male in entire antennal length and V nymphal instar to adult female in abdomen width.

3. *R. fuscipes* and *R. marginatus*

R. fuscipes and *R. marginatus* have almost similar values of I to II nymphal instar in postocular length, width between eyes and head width; II to III nymphal instar in width between eyes; III to IV nymphal instar in pedicel length; IV to V nymphal instar in postocular length and prothorax length; V nymphal instar to adult male in anteocular length,

diameter of eye, head width and entire rostral length and V nymphal instar to adult female in width between eyes and entire rostral length.

4. *R. kumarii* and *R. longifrons*

R. kumarii and *R. longifrons* have almost similar values of I to II nymphal instar in anteocular length, scape length, first flagellar segment length, medial rostral segment length and prothorax width; II to III nymphal instar in anteocular length; III to IV nymphal instar in width between eyes and head length; IV to V nymphal instar in second flagellar segment length; V nymphal instar to adult male in postocular length, width between eyes, entire rostral length and foretibial length; V nymphal instar to adult female in terminal rostral segment length and entire rostral length.

5. *kumarii* and *R. marginatus*

R. kumarii and *R. marginatus* have almost similar values of I to II nymphal instar in basal rostral segment length; II to III nymphal instar in diameter of eye, head width, first flagellar segment length, entire antennal length, basal rostral segment length, prothorax length, midtibial length, hind tibial length and abdomen length; III to IV nymphal instar in first flagellar segment length, basal rostral segment length, entire rostral length and midtibial length; IV to V nymphal instar in pedicel length, basal rostral segment length, medial rostral segment length, entire rostral length, prothorax width, foretibial length and midtibial length; V nymphal instar to adult male in second flagellar segment length, entire antennal length, medial rostral segment length and abdomen width and V nymphal instar to adult female in anteocular length, head length, pedicel length, basal rostral segment length, prothorax width, abdomen length and abdomen width.

6. *longifrons* and *R. marginatus*

R. longifrons and *R. marginatus* have almost similar values of II to III nymphal instar in entire rostral length and prothorax width; III to IV nymphal instar in postocular length, head width, scape length and prothorax width; V nymphal instar to adult male in head length and V nymphal instar to adult female in diameter of eye, first flagellar segment length, second flagellar segment length and entire antennal length.

7. *R. fuscipes*, *R. kumarii* and *R. longifrons*

R. fuscipes, *R. kumarii* and *R. longifrons* have almost similar values of I to II nymphal instar in hind tibial length; III to IV nymphal instar in terminal rostral segment length and V nymphal instar to adult male in scape length, basal rostral segment length and hind tibial length.

8. *R. fuscipes*, *R. kumarii* and *R. marginatus*

R. fuscipes, *R. kumarii* and *R. marginatus* have almost similar values of I to II nymphal instar in entire rostral length and fore tibial length; II to III nymphal instar in scape length, pedicel length and foretibial length; III to IV nymphal instar in diameter of eye; IV to V nymphal instar in anteocular length, head length, entire antennal length, hind tibial length and abdomen width; V nymphal instar to adult male in abdomen length and V nymphal instar to adult female in head width and hind tibial length.

9. *R. kumarii*, *R. longifrons* and *R. marginatus*

R. kumarii, *R. longifrons* and *R. marginatus* have almost similar values of I to II nymphal instar in prothorax length;

III to IV nymphal instar in second flagellar segment length and hind tibial length; IV to V nymphal instar in width between eyes; V nymphal instar to adult male in midtibial length and V nymphal instar to adult female in scape length.

10. *R. fuscipes*, *R. longifrons* and *R. marginatus*

R. fuscipes, *R. longifrons* and *R. marginatus* have almost similar values of I to II nymphal instar in head length and III to IV nymphal instar in entire antennal length, prothorax length and abdomen length.

Conclusion

The growth rates indices analyses of four *Rhynocoris* species revealed that *R. kumarii* and *R. marginatus* are the highest affinity. In exactly similar value analysis, the highest affinity is found between *R. kumarii* and *R. marginatus* (nine characters), *R. fuscipes* and *R. kumarii* and *R. longifrons* and *R. marginatus* share four characters, *R. fuscipes* and *R. marginatus* (two characters) and *R. fuscipes* and *R. longifrons* (one character).

In almost similar value analysis also, the highest affinity is found in *R. kumarii* and *R. marginatus* (thirty two characters); *R. kumarii* and *R. longifrons* (fifteen characters), *R. fuscipes*, *R. kumarii* and *R. marginatus* (fourteen characters), *R. fuscipes* and *R. marginatus* (thirteen characters), *R. fuscipes* and *R. kumarii* (twelve characters), *R. longifrons* and *R. marginatus* (eleven characters), *R. fuscipes* and *R. longifrons* (nine characters), *R. kumarii*, *R. longifrons* and *R. marginatus* (six characters), *R. fuscipes*, *R. kumarii* and *R. longifrons* (five characters) and *R. fuscipes*, *R. longifrons* and *R. marginatus* (four characters).

The cluster analysis of growth rates indices revealed that *R. kumarii* and *R. marginatus* are greater affinity among the four *Rhynocoris* species. The dendrogram analysis also confirmed this observation by the following node of grouped characters in II to III nymphal instar DE and MTL (99.61%), HW and EAL (99.00%) and F₁L and PTL (97.63%); IV to V nymphal instar PL and MRL (99.45%) and BRL and FTL (98.02%) and V nymphal instar to adult female AOL and HL (97.93%).

The above findings and conclusions drawn suggest that growth indices could be used as intrageneric and interspecific markers in the multidisciplinary biosystematics of Reduviidae. The present study, a model or pilot study could be further expanded incorporating more number of species and genera to derive meaningful interpretation in biosystematics. Hence, growth indices could be used as an additional biosystematics tool along with existing morphological, morphometrical, biological, behavioural, cytological and molecular tools to realize a comprehensive multidisciplinary biosystematics approach.

Acknowledgements

The authors are grateful to the authorities of St. Xavier's College (Autonomous), Palayamkottai, Tamil Nadu, India for facilities. One of us (DPA) thanks Council of Scientific and Industrial Research (21 (0865)/11/EMR-II, 2012-2013 Dated 28.12.2011), Govt. of India, New Delhi for financial assistance.

References

1. Ambrose DP. Biological, behavioural and morphological tools in the biosystematics of

- Reduviidae (Insecta: Heteroptera: Reduviidae). Proceedings of the Indian Academy of Sciences (Animal Sciences), 1987;96(5):499-508.
2. Ambrose AD, Ambrose DP. Post-embryonic development growth index as a tool in the biosystematics of Reduviidae (Insecta: Hemiptera). Shashpa, 2004;11(2):105-115.
3. Ambrose AD, Ambrose DP. Morphometric Indices in the Biosystematics of Reduviidae (Insecta: Hemiptera), Indian Journal of Entomology, 2009;71(1):18-28.
4. Atchley WR. Components of sexual dimorphism in *Chironomus* larvae (Diptera: Chironomidae). American Naturalist, 1971;105(945):455-466.
5. Atchley WR, Martin JA. Morphometric analysis of differential sexual dimorphism in larvae of *Chironomus* (Diptera). The Canadian Entomologist, 1971;103(3):319-327.
6. Beck SD. Nutrition of the European corn borer, *Pyrausta nubilalis* (Hubn.) II. Some effects of diet on larval growth characteristics. Physiological Zoology, 1950;23:353-361.
7. Bliss CI, Beard RL. The growth of the head capsule in individual milkweed bugs. Annals of the Entomological Society of America, 1954;47(3):388-392.
8. Brooks WK. Report on the Stomatopoda collected by H.M.S. Challenger during the years 1873-76. The Voyage of the H.M.S. Challenger, Zoology, 1986;16:1-116.
9. Cuffney TF, Minshall GW. Life history and bionomics of *Arctopsyche grandis* (Trichoptera) in a Central Idaho stream, Holarctic Ecology, 1981;4(4):252-262.
10. Daly HV. Insect morphometrics. Annual Review of Entomology, 1985;30:415-438.
11. Dyar HG. The Number of Molts of Lepidopterous Larvae. Psyche, 1890;5(175-176):420-422.
12. Eddlemen, CD. Morphological and biometrical differentiation of the larval instars of mosquitoes. I. *Culex territans*. Annals of the Entomological Society of America, 1967;60(1):33-41.
13. Fontaine R, Pilon JG. Etude de la croissance postembryonnaire chez *Enallagma ebrium* (Hagen) (Zygoptera: Coenagrionidae). Annales de la Societe Entomologique du Quebec, 1979;24(2):85-105.
14. Gaines JC, Campbell FL. Dyar's role as related to the number of instars of the corn ear worm, *Heliothis obsoleta* (Fab.), collected in the field. Annals of the Entomological Society of America, 1935;28(4):445-461.
15. Ghent AW. Linear increment in width of the head capsule of two species of sawflies. The Canadian Entomologist, 1956;88(1):17-23.
16. Gould SJ. Allometry and size in ontogeny and phylogeny. Biological reviews of the Cambridge Philosophical Society, 1966;41(4):587-640.
17. Guppy JC. Some effects of temperature on the immature stages of the armyworm, *Pseudaletia unipuncta* (Lepidoptera: Noctuidae), under controlled conditions. The Canadian Entomologist, 1969;101(12):1320-1327.
18. Hensleigh DA, Atchley WR. Morphometric variability in natural and laboratory populations of *Culicoides variipennis* (Diptera: Ceratopogonidae). Journal of Medical Entomology, 1977;14(4):379-386.
19. Hoxie RP, Wellso SG. Cereal leaf beetle 1 instars and sex, defined by larval head capsule widths. Annals of

- the Entomological Society of America,1974:67(2):183-186.
20. Hutchinson GE, Tongring N. The possible adaptive significance of the Brooks-Dyar rule. *Journal of Theoretical Biology*,1984:106(3):437-439.
 21. Kishi Y. Reconsideration of the method to measure the larval instars by use of the frequency distribution of head-capsule widths or lengths. *The Canadian Entomologist*,1971:103(7):1011-1015.
 22. Kovach WL. MVSP - A MultiVariate Statistical Package for Windows. Ver.: 3.1. Kovach Computing Services, Pentraeth, Wales, UK, 2007.
 23. Mackay RJ. Larval identification and instar association in some species of *Hydropsyche* and *Cheumatopsyche* (Trichoptera: Hydropsychidae). *Annals of the Entomological Society of America*,1978:71(4):499-509.
 24. McCreadie JW, Colbo MH. Allometry in the last larval instars of *Simulium truncatum* (Lundström) and *S. rostratum* (Lundström) (Diptera: Simuliidae). *The Canadian Entomologist*,1990:122(6):1137-1140.
 25. Miles HW. Growth in the larvae of Tenthredinidae. *The Journal of Experimental Biology*,1931:8(4):355-364.
 26. Mizell RF, Nebeker TE. Number of instars of the Southern pine beetle (Coleoptera: Scolytidae) and some comparisons of head capsule widths. *Annals of the Entomological Society of America*,1979:72(2):313-316.
 27. Nijhout HF. The control of body size in insects. *Developmental Biology*,2003:261(1):1-9.
 28. Peterson A, Haeussler GJ. Some observations on the number of larval instars of the Oriental peach moth, *Laspeyresia molesta* Busck. *Journal of Economic Entomology*,1928:21(6):843-852.
 29. Rohlf FJ. Morphometrics. *Annual Review of Ecology, Evolution, and Systematics*,1990:21:299-316.
 30. Rukmani J. Multidisciplinary Tools in the Biosystematics of Reduviidae (Insecta- Heteroptera-Reduviidae). *Ph.D. thesis, Madurai Kamaraj University, Madurai, India*,1992, 1-214.
 31. Taylor RL. On "Dyar's Rule" and its application to sawfly larvae. *Annals of the Entomological Society of America*,1931:24(3):451-466.
 32. Wignall AE, Taylor PW. Growth and development of an araneophagic assassin bug, *Stenolemus bituberus* (Heteroptera: Reduviidae). *Australian Journal of Zoology*,2008:56(4):249-255.