Effect of temperature on minor invertebrate predator reduviid *Isyndus heros* (Fab.) (Hemiptera: Reduviidae)

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Reduviid predators are the largest terrestrial bugs considered to be potential biocontrol agents and an integral part of integrated pest management (IPM). Despite the rich fauna of reduviids and their prey records, potential studies on reduviid are relatively meagre. Understanding the biotic and abiotic factors influencing the reduviid population is essential to exploit them as biocontol agents in agriculture. Hence the present study was aimed at determining the abundance of reduviid, *Isyndus heros* in an organic mango orchard and to determine the impact of abiotic factors on its occurrence. The peak population of reduviids was found during the initial flowering phase (January) and vegetative phase (September–December). Correlation matrix showed that there was a significant positive correlation of between the population of *I. heros* and relative humidity, and significant negative correlation between maximum and minimum temperatures. Further, the significant variables were regressed and the highest coefficient of determination was found in maximum temperature (R^2 = 0.62) with a single weather factor. However, multiple regression analysis revealed that the maximum and minimum temperatures could explain the variability up to 49%. This forms a baseline for the conservation and augmentation of reduviids that can be utilized as potential biocontrol agents in IPM programmes.

Keywords: Abiotic factors, biocontrol agents, mango orchard, reduviid predator.

REDUVIID (Hemiptera: Reduviidae) predators are the largest terrestrial bugs consisting of 7000 species[1] and subspecies, 913 genera and 25 subfamilies[2]. In India, there are about 464 species belonging to 144 genera and 14 subfamilies[3,4]. Despite the abundance of the world's reduviid fauna and its rich taxonomic, geographical, ecological, trophic, morphological, biological and behaviour diversity, studies regarding the temperature effects on reduviid are relatively meagre[3]. If the reduviids have to be conserved and augmented[5], a comprehensive and elaborate understanding of bioecology vis-a-vis climate is needed[6–8]. The objective of the present study is to analyse the population dynamics and impact of abiotic factors, especially temperature on *Isyndus heros* in an organic mango orchard.

Global warming has been one of the main focal themes in climate change deliberations[8]. Population dynamics of insect pests may be severely affected by climate change resulting in the decline of crop yields[9]. In most cases the studies are centred on food crops or higher animals, often forgetting that smaller invertebrates which form important links in the food web are equally significant[10]. However, the fact is that the smaller invertebrates are also affected, especially class Insecta, which are poikilotherms and hence more sensitive to temperature fluctuations[11].

Increase in temperature due to climate change may cause migration of insects from one region to another, as observed in the case of Edith's checkerspot butterfly which migrated towards the North Pole[12]. Climate change may also favour higher growth rate and reproduction in insects[13]. Several studies on aphids and moths have suggested that enhanced temperature levels have aided faster wing development resulting in quicker dispersal[14,15]. Climate change may be beneficial in few geographical regions since the temporal variation in temperature regimes may render such places unsuitable for existing pests[16].

Global warming may encourage the migration of pests to newer areas[17]. Rise in temperature by 3°C would result in decrease of 90% population of predatory wasp (*Cotesia marginiventris*). Hence slight increase in temperature may lead to loss of beneficial insects and increase in damage caused by caterpillar species which may warrant insecticide operations[18]. However, the tropical insects which come within the ambit of a set of temperatures and have adapted to a temperature regime are easily affected by warmer climate, resulting in their extinction[19]. Extinction of such insects, even if local, can affect ecosystem services like pollination.

Most of the available literature on the effects of temperature on insects is on herbivores[8]. Studies on carnivorous insects, which are essentially predaceous, are few and far between. It is not clear whether temperature would favour a boom or decline in predacious insects that thrive on herbivores. Abbot *et al.*[20] using temperature models suggested that predation by coccinellids may increase if the prey, an aphid, is favoured by higher temperature. However, studies on predatory insects in a field on a temporal scale alone will indicate if temperature rise affects insect predator positively or negatively. To examine this we conducted a study on the reduviid bug *I. heros* in an unsprayed organic mango orchard.

A detailed study was conducted at ICAR-Indian Institute of Horticultural Research (ICAR-IIHR; 12°58′N; 77°35′E), Bengaluru, India in a 20-year-old organic mango orchard of cv. Totapuri. Organic orchard was chosen to ensure the presence of *Isyndus heros* and its preys, viz.

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Table 1. Correlation between *Isyndus heros* and weather parameters

Weather parameters	June–December 2013	January–December 2014	January–December 2015	Pooled
Maximum temperature (°C)	–0.63*	–0.65*	–0.61*	–0.65*
Minimum temperature (°C)	–0.32*	–0.49*	–0.40*	–0.40*
Relative humidity (%)	0.34*	0.33*	0.23*	0.24*
Wind speed (km/h)	0.12	–0.07	–0.24	–0.04
Rainfall (mm)	0.11	–0.06	0.09	–0.02

*Significant $P = 0.05$.

Table 2. Polynomial regression equations of *I. heros* population based on weather parameters

		Pooled (2013–15)	
Regression models	Temperature (°C)	Regression equation	R^2
Polynomial	Maximum temperature	$y = 0.031x^2 - 2.238x + 39.17$	0.62
	Minimum temperature	$y = 0.027x^2 - 1.410x + 17.97$	0.57
Linear	Maximum temperature	$y = -0.363x + 11.65$	0.44
	Minimum temperature	$y = -0.272x + 6.263$	0.37
Poisson	Maximum temperature	$y = 7.986 - 0.2764x$	0.36
	Minimum temperature	$y = 2.599 - 0.1334x$	0.18

leafhoppers (*Idioscopus nitidulus*, *I. niveosparsus*, *I. clypealis*, *Amritodus atkinsoni*), aphids, mealybugs, caterpillars (*Orthaga euadrusalis*), etc. in the ecosystem and to preclude the negative effects of chemical sprays. The reduviid numbers were estimated by visual counts. Observations were made on the nymphs and adults of reduviids. For each sampling, five random panicles or fresh shoots were selected from the tree. Twenty-eight trees were sampled at weekly intervals from the second week of June 2013 to the fourth week of December 2015, constituting 140 sampling units per day. The total number of observations ($n = 255$) comprised of 35,700 sampling units for 31 months. Data were tabulated and average reduviids/tree was documented. Observations on population build-up of both nymphs and adults were recorded at morning hours (9.30–10.30 am), since winged insects are sluggish and can be easily counted. *I. heros* occurs in both vegetative and flowering phase of mango; hence the population of reduviids was recorded throughout the year.

The weather parameters, viz. maximum and minimum temperatures (°C), relative humidity (%), total rainfall (mm) and wind speed (km/h) of the selected site were collected each day from the meteorological section of ICAR-IIHR from June 2013 to December 2015. The weekly means were subsequently utilized to correlate with the occurrence of predator in the study period of 31 months. Data were analysed using correlation and regression to obtain the extent of variability by weather parameters that influence the abundance of reduviids in an organic mango orchard[21].

The population dynamics of *I. heros* is shown in Figure 1, when the data for 31 months have been pooled; higher population was found during December 2013, July and December 2014, as well as September and December 2015. The highest number of reduviids was recorded in December 2013, when their population was found to be 5.32/tree/day. As seen in Figure 1, the population of the reduviids fluctuated throughout the year. The average number of reduviids in 31 months of the study ranged between 0.00 and 5.3/tree/day. In summer months (March–June in 2014 and 2015), the population was very low, attributing the probable role of temperature in limiting the number of reduviids (Figure 1). Therefore, analysis of the relationship between counts of *I. heros* and weather parameters was carried out.

During 31 months of the study, there was significant negative correlation between reduviid population and maximum and minimum temperatures and a positive correlation between the reduviid population and relative humidity. There was no significant correlation between reduviid population and wind speed as well as rainfall (Table 1).

The significant weather variables were regressed to explain the extent of variability of reduviid population with respect to weather parameters. Since there was no difference between yearwise and pooled correlations, the pooled data were utilized for regression analysis. The Poisson regression model and linear model had R^2 of 0.18 and 0.44 respectively (Table 2). However, in the polynomial model, the coefficient of determination of maximum and minimum temperatures was 0.62 and 0.57 respectively. This showed that the variation in reduviid population declined with maximum and minimum temperatures (Figures 2 and 3). Dynamics of *I. heros* was

Table 3. Multiple regression equation of *I. heros* population based on temperature

Pooled	Regression equation	R^2
Maximum and minimum temperature	$y = 12.01 - 0.28x_1 - 0.13x_2$	0.49

x_1, Maximum temperature; x_2, Minimum temperature.

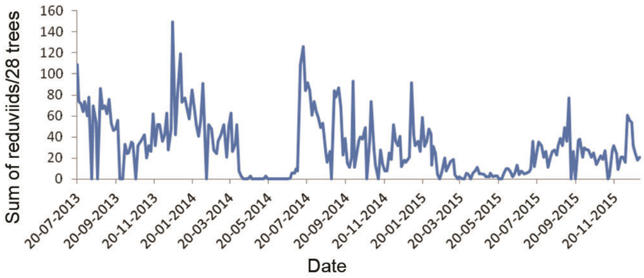

Figure 1. Population dynamics of *Isyndus heros* in an organic mango orchard from June 2013 to December 2015 (pooled).

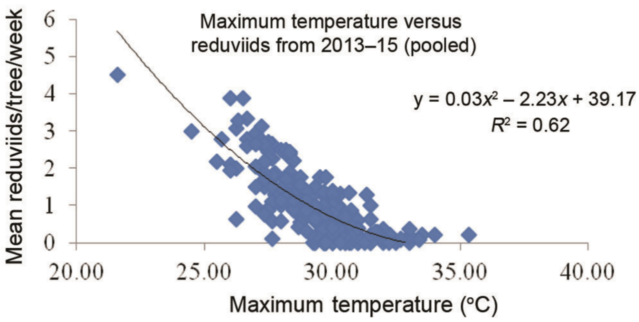

Figure 2. Effect of maximum temperature on *I. heros* population in an organic mango orchard.

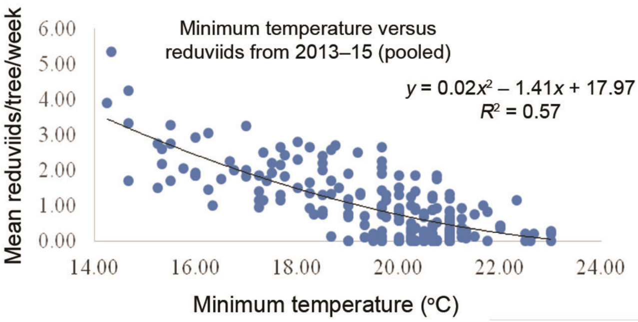

Figure 3. Effect of minimum temperature on *I. heros* population in an organic mango orchard.

best explained using the polynomial equation (Table 2). This clearly indicates that there is a definite relationship between temperature and population dynamics of reduviid bug. Studies on relationship between temperature and hatching of reduviid *Triatoma brasiliensis* suggested that high rate of hatching was found in the temperature range 25°–27°C, while no hatching was observed at 12°C, 19°C and 38°C, suggesting that higher and lower temperature regimes restrict the reduviid population. The highest number of eggs was found in the temperature range 28°C and 32°C (ref. 22).

Further, multiple regression analysis was done using the significant weather parameters, viz. maximum and minimum temperatures, which accounted to an extent of 49% (Table 3). However, maximum temperature alone could explain the variability up to 62% (Table 2). Therefore, it is evident that maximum and minimum temperatures independently influence the reduviid population. Temperature effects on development and survival of reduviid *Pristhesancus plagipennis* have been studied earlier[23]. It was found that survival of nymphs was the highest in the temperature range 25°–30°C. However, fastest development of nymph and egg was recorded at 32°C and 32.5°C respectively[23].

In the present study, reduviid population declined with hotter weather characterized by reduced humidity. Thus, effects of temperature and humidity show opposite trends, again a proof that higher temperature which brings down humidity results in low reduviid population. Similar studies on reduviid *Triatoma infestans* found that egg-laying was higher at 29°C and 26°C, which followed a bimodal pattern with 40% relative humidity[24].

The present results indicate that reduviids thrive in maximum temperature gradient between 25°–29°C and tend to decline beyond this range; temperature alone could explain variability in reduviids up to 62%. This study shows that an invertebrate predator like *I. heros* can be vulnerable to increased temperature or global warming.

Thus temperature seems to be critical for *I. heros* and any temperature rise beyond 32°C in the micro climate of mango orchard will not support the reduviid bug. Studies conducted in reduviid, *Rhodnius prolixus* suggested that there is retardation in development above 34°C and no hatching of eggs beyond 36°C (ref. 25). As reduviids are important micro predators in the invertebrate world, there is a need for similar studies on other minor predators. Distribution of Oriental fruit fly (*Bactrocera dorsalis*) was studied using CLIMEX software to know the influence of climate change in different time-frames (2030, 2050, 2070 and 2090) in India. The study has suggested that increase in temperature and decrease in cold stress may promote shift of the pest from southern India towards northern parts of the country, especially Jammu and Kashmir by 2090 (ref. 11).

Interestingly, impact of temperature may also point to possible distribution of *I. heros*. Generally this predator occurs more in cooler climates like the Deccan Plateau or boarder coastal belts. It is expected to be found in the hills with lower temperature. Thus, in the hot plains of India where the temperature is >40°C, *I. heros* is unlikely to occur. With current interest of the impact of global warming on biotic organism, this study would lead to better understanding of the influence of weather on minor invertebrates such as reduviids that are useful predators of other phytophagous insects like cicadellids.

1. http://www.cirrusimage.com/bugs_assassin_zelus_luridus.htm (accessed on 9 September 2016).
2. Capriles, J. M., *Systematic Catalogue of the Reduviidae of the World (Insecta: Heteroptera)*, University of Puerto Rico, 1990, p. 694.
3. Ambrose, D. P., A checklist of Indian assassin bugs (Insecta: Hemiptera: Reduviidae) with taxonomic status, distribution and diagnostic morphological characteristics. *Zoos Print J*., 2006, **21**, 2388–2406.
4. Sahayaraj, K., Reduviids and their merits in biological control. In *Basic and Applied Aspects of Biopesticides*, Springer India, 2014, pp. 195–214.
5. Schaefer, C. W., Reduviidae (Hemiptera: Heteroptera) as agents of biological control. *Bicovas*, 1988, **1**, 27–33.
6. Ambrose, D. P., Assassin bugs of Tamil Nadu and their role in biological control (Insecta: Heteroptera: Reduviidae). In *Advances in Biological Control Research in India* (eds Joseph, J. K. and Abdurahiman, U. C.), M./S. Printex Ltd, Calicut, 1987, pp. 16–28.
7. Ambrose, D. P., Biocontrol potential of assassin bugs (Hemiptera: Reduviidae). *J. Exp. Zool*., 2003, **6**, 1–44.
8. Bale, J. S. *et al.*, Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biol.*, 2002, **8**, 1–6.
9. Gray, D. R., The relationship between climate and outbreak characteristics of the spruce budworm in eastern Canada. *Climate Change*, 2008, **87**, 361–383.
10. Memmott, J., Martinez, N. D. and Cohen, J. E., Predators, parasitoids and pathogens: species richness, trophic generality and body sizes in a natural food web. *J. Anim. Ecol.*, 2000, **69**, 1–15.
11. Sridhar, V., Verghese, A., Vinesh, L. S., Jayashankar, M. and Jayanthi, P. K., CLIMEX simulated predictions of Oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) geographical distribution under climate change situations in India. *Curr. Sci*., 2014, **106**, 1702–1710.
12. Parmesan, C., Ecological and evolutionary responses to recent climate change. *Annu. Rev. Ecol. Evol. Syst*., 2006, **37**, 637–669.
13. Verghese, A., Madhura, H. S., Kamala Jayanthi, P. D. and Stonehouse, J. M., Fruit flies of economic significance in India, with special reference to *Bactrocera dorsalis* (Hendel). In Proceedings of 6th International Fruit Fly Symposium, Stellen-Bosch, South Africa, 2002.
14. Woiwod, I. P. and Harrington, R., Flying in the face of change: the Rothamsted insect survey. In *Long-Term Experiments in Agricultural and Ecological Sciences* (eds Leigh, R. A. and Johnson, A. E.), CAB International, Wallingford, UK, 1994, pp. 321–342.
15. Fleming, R. A. and Tatchell, G. M., Shifts in the flight periods of British aphids: A response to climate warming? In *Insects in a Changing Environment* (eds Harrington, R. and Stork, N. E.), Academic Press, London, 1995, pp. 505–508.
16. Kiritani, K., Predicting impacts of global warming on population dynamics and distribution of climate and outbreak characteristics of the arthropods. *Japan Popul. Ecol*., 2006, **48**, 5–12.
17. Hance, T., Van Baaren, J., Vernon, P. and Boivin, G., Impact of extreme temperatures on parasitoids in a climate change perspective. *Annu. Rev. Entomol.*, 2007, **52**, 107–126.
18. Raza, M. M., Khan, M. A., Arshad, M., Sagheer, M., Sattar, Z., Shafi, J. and Ishfaq, I., Impact of global warming on insects. *Arch. Phytopathol. Plant Protect*., 2015, **48**, 84–94.
19. Deutsch, C. A., Tewksbury, J. J., Huey, R. B., Sheldon, K. S., Ghalambor, C. K., Haak, D. C. and Martin, P. R., Impacts of climate warming on terrestrial ectotherms across latitude. *Proc. Natl. USA*, 2008, **105**(18), 6668–6672.
20. Abbot, K. C., Harmon, J. P. and Fabina, N. S., The challenge of predicting temperature effects on short-term predator–prey dynamics. *Popul. Ecol.*, 2014, **56**, 375–392.
21. Little, T. M. and Hills, F. J., *Agricultural Experimentation (Design and Analysis)*, John Wiley, New York, USA, 1978, p. 368.
22. Guarneri, A. A., Lazzari, C., Xavier, A. A. P., Diotaiuti, L. and Lorenzo, M. G., The effect of temperature on the behaviour and development of *Triatoma brasiliensis*. *Physiol. Entomol*., 2003, **28**, 185–191.
23. James, D. G., Effect of temperature on development and survival of *Pristhesancus plagipennis* (Hem: Reduviidae). *Entomophaga*, 1992, **37**, 259–264.
24. Lazzari, C. R., Temperature preference in *Triatoma infestans* (Hemiptera: Reduviidae). *Bull. Entomol. Res*., 1991, **81**, 273–276.
25. Clark, N., The effect of temperature and humidity upon the eggs of the bug, *Rhodnius prolixus* (Heteroptera, Reduviidae). *J. Anim. Ecol.*, 1935 **4**, 82–87.

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