Climatic Factors Related to Chagas Disease Transmission

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The relations between certain climatic factors and Chagas disease vectors and infection have been studied almost since the beginning of the disease's parasitological, clinical, and epidemiological descriptions. As early as four years after Carlos Chagas original publication of a new pathological entity, Neiva (1913) conducted experimental work to determine the influence of temperature on the evolution of *Triatoma infestans* embryos. He demonstrated that experimental warming accelerates the embryonic period.

Several studies focusing on the influence of temperature on vector species were performed with different species. However, the most important studies were devoted to those species recognized as domiciliated vectors of epidemiological significance. Hack (1955) observed that in geographic areas with high temperatures, *T. infestans* (Klug, 1834) has two generations per year, while in temperate areas it has only one generation during the same period. Carcavallo and Martínez (1972) obtained shorter life cycles in specimens of three species of the genus *Triatoma* Laporte, 1832, reared at permanent high temperature (27-28°C) as compared to colonies reared out-of-doors at variable temperatures, including some cold periods during winter. Zeledón et al. (1970) observed that *T. dimidiata* (Latreille, 1811) eggs hatched at 29 days when reared at 22-24°C and at 23 days when reared at 26°C.

Several important studies on the same topic, the development and life cycle of Triatominae species, were published by Silva (1986) and Silva and Silva (1986 a, b, c, 1988, among other publications by the same authors). They compared the life cycles of species reared at 25 and 30°C. Results for different species were, respectively, 248 and 190 days in *T. matogrossensis* Lent & Barbosa, 1953, 145 and 114 days in *Rhodnius nasutus* Stal, 1859, 230 and 186 days in *T. vitticeps* (Stal, 1859), 181 and 152 days in *Panstrongylus megistus* (Burmeister 1835), and 181 and 134 days in *T. infestans.*

The endemic area of infection by *Trypanosoma cruzi* in animal reservoirs and humans is smaller than the geographical vector distribution area, especially in the Northern hemisphere. One species, *T. sanguisuga* (Leconte, 1855), is found in most of the United States territory, including some states near the border with Canada, such as Indiana and Illinois. Human infection is exceptional in the United States, and vectors are mainly related to wild reservoirs like spiny rats of the genus *Neotoma.* Prevalence of vectors in areas with cold winters could be explained by the microclimatic conditions of reservoir habitats, generally many degrees Celsius warmer than the external environment. Similar observations should be made in relation to the Southern hemisphere, where species like *T. infestans*, *T. patagonica* Del Ponte, 1929, and *T. platensis* Neiva, 1913 are found in the Patagonian plateau with low temperatures between -5 and -15°C during the cold season. In the specific case of *T. infestans*, its adaptation to the human domestic environment is the best protection against the extreme cold, because dwellings usually have a microclimate with temperatures adapted to human comfort.

Curto de Casas and Carcavallo (1984) studied the southern dispersion of Triatominae species and concluded that the critical climatic factor is the number of days with temperatures above 20°C and not the lowest temperature, as was supposed. Most locations where triatomine species are found in the Patagonian region have more than eight months in most days have temperatures of 20°C or higher, while the average temperature during the coldest month does not go below 0°C. This confirms the publication by Blaksley and Carcavallo (1968), who studied resistance to cold by nine species of genus *Triatoma* and found that only a few specimens died after 4 hr at -2°C. The extreme case was *T. platensis*: no mortality at -4°C (N=39 specimens), only two out of 20 specimens died at -6°C, and one female oviposited at -4°C, but the egg did

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not show vital activity during four days of observation. The species most affected by cold temperatures was *T. rubrovaria* (Blanchard, 1843), with a 83% mortality rate at -2^{o}C and 100% at -4^{o}C.

Catalá (1991) studied the feeding frequency of *T. infestans* under natural climatic conditions in experimental chicken coops over a 1-year period and showed that temperature has a dominant effect on the biting rate, with a similar seasonal pattern for each stage. The proportion of fed bugs (PFB) was 0.014 in July (winter) and 0.470 in December (spring/summer). The importance of feeding frequency in the life cycle of Triatominae bugs was demonstrated by Carcavallo et al. (1978) in *R. prolixus*. Colonies feeding every eight days completed the nymphal stages in 78.9 days, while those fed every 16 days reached the adult stage in 107.1 days and those fed every 28 days reached adulthood in 199.7 days.

Burgos et al. (1994) and Curto de Casas et al. (1994) developed a methodology to study the climatic influence on the geographical distribution of Triatominae species, especially *T. infestans*, and pointed out that high temperatures would accelerate insect metabolism, while low relative humidity (air saturation deficit) would increase the feeding frequency in relation to dehydration and that blood meals provide an important amount of water. These authors correlated two climatic factors: the thermal index, defined as the total number of days with temperatures above 20^{o}C, and the dryness index, the annual amount of daily saturation deficit; the air saturation deficit is the vapor tension that is missing in order to reach saturated humidity. With the information gathered by weather stations in Argentina and other American countries, they prepared a classification of different species in relation to both climate and biomas, following the Holdridge diagram for tropical and subtropical Triatominae species. For species prevalent in temperate areas, they marked locations where a given species was found as dots on a diagram with thermal and dryness indexes.

In relation to geographical factors linked to climatic conditions of vector species, several papers have been published with maps and diagrams in which latitude and altitude were correlated: Carcavallo et al. (1995), Curto de Casas et al. (1996), Galíndez et al. (1996), Jurberg et al. (1996), and Galvão et al. (1998). Most of the species are found in tropical and subtropical areas and altitudes ranging from 100 to 1,800 m.o.s.l. However, the most important vector species, *T. infestans*, is found at higher altitudes (4,100 m.o.s.l. in Bolivia) and latitudes (the border between Chubut and Santa Cruz provinces in the Argentinian Patagonia).

The importance of the microclimate in the habitat has been pointed out by several authors. Pifano (1969) studied the temperature inside the palm tree *Scheelea humboldtiana* and found that it is constant, 22-23^{o}C, while on the external leaves it varies from 16 to 30^{o}C. Humidity is high in the inner parts of the palm but can vary from 40 to 95 % on the external leaves. This shows that according to seasonal variations, triatomine bugs, specially of the genus *Rhodnius*, may choose the best conditions of temperature and humidity by moving around inside the tree. Lazzari et al. (1998), using sensors linked to data-loggers, simultaneously recorded every 12 min during 15 days, in domestic and peridomestic habitats, temperature and relative humidity in a rural house in Argentina. Results for that endemic area for *T. infestans* showed no statistically significant differences between the average temperature outside and inside the structures inside the dwelling. But they found a marked asymmetry in the dynamics of relative humidity changes: increases outside were followed by a delay in the structures with values rather lower than the external RHs, while decreases of outside RH were followed almost immediately by RH inside refuges, reaching values closer to the external low. These authors conclude: "these results are remarkably consistent with the spontaneous preference of *T. infestans* for dry environments..."

Asin and Catalá (1995) found that high temperatures accelerate the development of *T. cruzi* in the digestive tube of *T. infestans*: when reared at 30^{o}C, trypomastigotes appeared in feces 32 days after the infective meal, while in specimens reared at 28^{o}C, trypomastigotes were seen on the 24th day. Even though most triatomine species can be reared under laboratory conditions at 26-28^{o}C and 60-70% RH, some species need higher or lower values for these climatic factors. According to the forecast that a global warming is in process and will have different kinds of effects during the next several decades, better knowledge of the relationship between climatic factors and Chagas disease epidemiology is needed.

Higher temperatures could extend the geographical distribution of wild vectors; lower humidity may shorten the life cycle.

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