PERIDOMESTIC STRUCTURE, FARMING ACTIVITY AND TRIATOMINE INFESTATION

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Summary:

The role of peridomestic structure and farming activity on triatomine infestation was studied on two vector species of Chagas disease (*Triatoma pseudomaculata* and *T. brasiliensis*) in Bahia State, northeastern Brazil. A randomly selected population issued from 136 farms was divided into four categories according to the householder activity. At regional scale, the dwellings of farmers working on degraded land of irrigated farms are less exposed to *T. pseudomaculata* infestation. At premises scale, the farmers and casual workers, who have smaller peridomiciles and less cattle, are also less exposed to *T. pseudomaculata*. The association of *T. brasiliensis* with the most mobile populations (casual workers and young breeders) suggests a passive transport of this competitive species. Finally, the retired farmers that own large premises and cattle, but have more sedentary behavior, are the most exposed to *T. pseudomaculata* infestation.

KEY WORDS : Chagas disease, *Triatoma pseudomaculata*, *Triatoma brasiliensis*, dwelling infestation, peridomicile, human behavior, animal husbandry, Brazil.

Résumé : STRUCTURES PÉRIDOMICILIAIRES, ACTIVITÉS AGRO-PASTORALES ET INFESTATION PAR LES TRIATOMES

*Le rôle des structures du péridomicile et des activités d'élevage a été étudié à propos de deux vecteurs de la maladie de Chagas (*Triatoma pseudomaculata *et* T. brasiliensis*), dans l'état de Bahia, au nord-est du Brésil. La population de 136 fermes, tirées au sort, a été séparée en quatre catégories, en fonction du type d'activité des fermiers. À l'échelle régionale, les demeures des fermiers travaillant sur les terres dégradées des zones d'agriculture irriguée sont moins exposées à l'infestation par* T. pseudomaculata. *À l'échelle des péridomiciles, les agriculteurs et les journaliers, qui ont de plus petits péridomiciles et moins de bétail, ont aussi des unités d'habitation moins exposées à l'infestation par* T. pseudomaculata. *L'association de* T. brasiliensis *avec la population la plus mobile (journaliers et jeunes éleveurs) suggère un transport passif de cette espèce compétitive. Enfin, les éleveurs retraités, qui ont de vastes péridomiciles et de grands troupeaux, mais un comportement plus sédentaire, sont plus exposés à l'infestation par* T. pseudomaculata.

MOTS CLÉS : *maladie de Chagas,* Triatoma pseudomaculata, Triatoma brasiliensis, *infestation, habitat, péridomicile, comportement humain, élevage, Brésil.*

INTRODUCTION

The elimination of *Triatoma infestans*, the main vector of Chagas disease, was successful over the northeastern Brazil. The control of this imported species has highlighted the synanthropic process of autochthonous Triatominae originally restricted to wild environment or previously occulted by *Triatoma infestans* invasion. These emergent species invade the peridomestic areas, coming from the surrounding environment. They colonize artificial structures where they maintain the epidemiological cycle of *Trypanosoma cruzi* close to man. The silvatic triatomines in process of domestication may play an important role in the transmission of Chagas disease. It is the case of *Triatoma brasiliensis* (Neiva, 1911) (Neiva & Penna, 1916) and *Triatoma pseudomaculata* (Corrêa & Espínola, 1964) that are increasingly reported invading artificial structures (Dias *et al.*, 2002, Costa *et al.*, 2003). Both species are ubiquitous throughout the caatinga ecosystem and are among the three more frequent triatomines captured in man-made structures of this region, mainly in the peridomicile (Silveira & Vinhaes, 1998; Silveira *et al.*, 1998; Costa *et al.*, 1998; Oliveira-Lima *et al.*, 2000; Sarquis *et al.*, 2004). In natural environment, *T. pseudomaculata* occurs in hollow tree and bird nest when *T. brasiliensis* is found in rocky habitat. Their synanthropic process is probably promoted by anthropogenic environmental changes.

From the 17th century, farmers have progressively settled in northeastern Brazil where they have developed animal husbandry (cow and, subsequently, goat and sheep). Intense farming activities resulted in the degradation of primitive forest and succeeding damage to triatomine silvatic biotopes. Simultaneously, many artificial structures built by the farmers have provided new habitats for triatomines. However, the combined influence of population type, residence pattern and practices of husbandry, remains little known on the triatomine infestation. The aim of this study was to pro-

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vide an analysis of these factors among a farming population of northeastern Brazil. The family groups were firstly classified into different categories, according to the activity (agriculture or husbandry) and the way to exercise it. The peridomicile organization and its possible infestation by triatomine bugs were then documented for each category.

MATERIALS AND METHODS

Study area

Curaça is a rural district of 6,406 km^2 situated in the Bahia State, Brazil (8° 59' S; 39° 54' W). The area has expanded progressively because of livestock farming and the small city of Curaçá was founded in 1832 as harbor on the São Francisco River. Out of almost 29,000 inhabitants, 18,000 are living in the rural area where they practice mainly the farming. The irrigation was introduced in the land located along the São Francisco River several decades ago. More than 60 % of the population is currently living along the river where fruit and vegetable are produced. The rest of the population lives in isolated farms in the middle of a globally degraded caatinga with, however, large patches of more preserved vegetation. It mainly rears goat, sheep, and a few cattle. This rural district, that exhibits high rates of poverty, inequality and social exclusion combined with low rates of education and employment, is one of the more deprived of Brazil (Pochmann, 2003).

Survey design

From September to November 2002, a survey of 136 farms randomly selected was carried out in the Curaça district. One third of the sample population was farmers living in the agricultural zone near the São Francisco River, and the rest lived inland of livestock. The last group was homogeneously distributed into two main zones of vegetation, both pertaining to the *caatinga*: *i*) region near Curaça characterized by damaged vegetation due to intense livestock rearing; *ii*) preserved shrub land. All visited domiciliary units (including domicile and peridomicile with annexes) were carefully mapped and described. Houses were built from stick covered with mud (*taipa*), raw mud bricks (adobe), artisanal or industrial bricks and cement. The roofs were always made of local or industrial tiles. The peridomicile was defined as the full area located around the house and supporting useful annexes for men and animals. A standard questionnaire concerned with the family origin and composition, ownership of house, type and number of animals, daily farmer's activities and main income sources, was filled out according to the responses of each householder. Informal interviews were directed toward the history of the district and farmer biography.

Insect capture

Various potential habitats were searched for the presence of triatomines in the domicile and peridomicile. Each dwelling was investigated for approximately one hour by a trained technician of the Chagas Disease Control program. The collected bugs where conserved in a labeled plastic box with filter paper, using one box for each capture site, and sent to laboratory for further analysis. We considered that a domiciliary unit was infested if, at least, one living bug was captured inside the house or peridomicile.

Data analyses

The population surveyed was classified into different categories, depending on the main activity (agriculture, animal rearing, casual work and unemployed), existence of a retirement pension, and main source of income (sale of animals or agricultural products, retirement pension, occasional work, employee by a breeder). Of the 136 visited dwellings, four were excluded because householders were not agro-pastoralists but employees of public service. The following data were computed as nominal variables of two or three classes: family composition (single/couple/family); age of domicile (< 20 years/≥ 20 years); surface of domiciliary unit (< 2,000 m^2/> 2,000 m^2); surface of house (small < 40 m^2/middle size between 40 and 60 m^2/large ≥ 60 m^2); building material (*taipa*/adobe/brick or commercial material); presence of piles of material inside the peridomicile (yes/no); number of pens (< 3/≥ 3); surface of pens (small < 150 m^2/middle size 150-550 m^2/large ≥ 550 m^2); length of pen fences (< 80 m/≥ 80 m); roofed pen (yes/no); number of goats or sheep (none/few < 100/many ≥ 100); number of cows (none/few < 15/many ≥ 15); number of dogs (< 3/≥ 3). The association between: *i*) the population category and variables concerning the domiciliary unit, and *ii*) population category and dwelling infestation, were tested by chi^2 or exact Fisher test. Data about daily life of farmers were issued from interviews.

RESULTS

Behavioral pattern of the population

Most of the farmers living near the São Francisco River were coming from inland farms or, sometimes, other Brazilian States, particularly Ceara, attracted by irrigation projects of the area. The population, for the most part, was constituted of families with young children and earned a living with

market gardening they practiced in irrigated fields. They had built houses close by each other and the labor in irrigated fields was their main activity. They only ventured into the *caatinga* for occasional hunting trips, plant collecting or firewood. The farms generally included a piece of land, further inland, where few livestock might be reared. Some farmers owned their farm while the others were regularly employed in neighboring farms. Casual workers were homogeneously distributed in the *caatinga* area and most of them were born in the district. They were generally young, single or just married, with no or few children. They lived in various types of dwelling that they owned, borrowed from family or occupied as temporary workers. They mainly worked toward maintaining the farm, sometimes in irrigated fields or collecting fruits in season. They walked across the *caatinga* for cattle rearing, hunting or collecting wild fruits, plants and wood. Exclusive and retired cattle farmers had similar activities but a slightly different way of life. Because cattle work was a full time activity, exclusive young farmers spent most of the day on horseback in the *caatinga* herding and watching on the animals. At noon, they often took a nap, sleeping in the shade of rock or tree. At night, they kept generally all the horse equipment inside dwelling. Unlike young cattle farmers, old people had less contact with *caatinga*. Old cattle farmers usually carried on rearing some animals but it was above all the retirement pension that gave them a regular income. They spent time in the farm for receiving their relatives and performing maintenance works.

Finally, four groups of people might be constituted:

1. Farmers: they practiced irrigated agriculture and lived near the São Francisco river; they were retired or not; they supported by market gardening or casual agricultural work;
2. Casual workers: they lived in the *caatinga* of casual work mainly related to cattle farming. They did not have any regular income except, sometimes received a retirement pension always supplemented by casual work;
3. Exclusive cattle farmers: they practiced intense animal farming and lived in the *caatinga* (with two exceptions); they were not retired and drew incomes from livestock sale or regular work for a wealthy landlord;
4. Retired cattle farmers: they were officially retired and lived in the *caatinga* but still practiced animal farming; they had retirement allocation completed with occasional sale of animals.

PERIDOMICILE STRUCTURING AND POPULATION GROUP

The investigated peridomiciles had an average of 8.3 ± 4.4 annexes. They were mainly made up of pens (3.1 ± 2.0) surrounded and divided by wood fences, brick or tile piles (2.7 ± 1.7), trees used as chicken coops, fowl houses and animal shelters. Generally, the organization of peridomestic structures was different between farmers and casual workers on the one hand, and cattle farmers (groups 3 and 4) on the other hand (Table I). In farmers and casual workers, the dwelling was more newly built, the pens smaller and the sheep and goat flock less important. In comparison with the three other groups, the farmers had smaller domestic units with a reduced peridomestic area and smaller cattle pen. The farmers were less involved in animal rearing than others groups and just rear few goats or sheep for their own needs. There was no difference between the groups in regard to building material of dwellings, the existence of brick and tile piles, the number of dogs and the immediate environment (preserved or damaged *caatinga*).

TRIATOMINE INFESTATION

In total, 359 triatomines were collected in 66 of the 131 domestic units investigated (50.4 %). *T. brasiliensis* was the dominant species in number of collected individuals (286 *vs* 73 *T. pseudomaculata* specimens). *T. brasiliensis* was collected alone in 41 domestic units, *T. pseudomaculata* alone in 18, and both species together in seven. The infestation rate according to the group of people is given in Table II. *T. pseudomaculata* infestation was positively associated with retired cattle farmers (p-value = 0.003) and negatively associated with farmers (p-value = 0.015). On the other hand, *T. brasiliensis* infestation was associated with none of the population categories (p-value = 0.098). When the population was pooled according to the peridomestic characteristics and livestock, both groups with larger structures and livestock (exclusive and retired cattle farmers) also presented the higher *T. pseudomaculata* infestation rate (26.8 % *vs* 8.9 %; p-value = 0.013). On the other hand, the size of structures and livestock had not influence on the *T. brasiliensis* infestation rate (37.3 *vs* 35.7 %; p-value = 0.86). When the population was pooled according to the way of life (contact with the caatinga and mobility), both groups with more sedentary behavior (farmers and retired cattle farmers) had the lowest *T. brasiliensis* infestation rate (27.1 % *vs* 47.5 %; p-value = 0.019). The lifestyle had not influence on the *T. pseudomaculata* infestation rate (21.4 *vs* 16.4 %; p-value = 0.51).

DISCUSSION

The study area belongs to the northeast semi-arid zone of Brazil where *T. brasiliensis* and *T. pseudomaculata* are autochthonous triatomines des-

Features of domestic unit	Category	No.	**Farmers** (30) No. (%)		**Casual workers** (26) **Exclusive farmers** (35) **Retired farmers** (40) No. (%)
Surface of the domestic unit	< 2,000 m²	57	24 (80)		33 (32.6)
	≥ 2,000 m²	74	6 (20)		68 (67.3)
	p-value			< 0.0001	
House surface	< 40 m²	36	13 (43.3)		23 (22.7)
	40-80 m²	43	12 (40)		31 (30.7)
	≥ 80 m²	52	5 (16.6)		47 (46.5)
	p-value			0.0092	
No. of cows	< 15	91	30 (100)		61 (60.3)
	≥ 15	40	0		40 (39.6)
	p-value			< 0.0001	
			Farmers (30) **Casual workers** (26)		**Exclusive farmers** (35) **Retired farmers** (40)
Age of house	< 20 years	45	26 (49.4)		19 (25.3)
	> 20 years	72	22 (39.2)		50 (66.7)
	p-value			0.0042	
Number of pens	< 3	56	36 (64.3)		20 (26.7)
	> 3	75	20 (35.7)		55 (73.3)
	p-value			< 0.0001	
Surface of pens	< 150 m²	42	24 (55.8)		18 (24.3)
	150-550 m²	50	11 (25.6)		39 (52.7)
	≥ 550 m²	25	8 (18.6)		17 (22.9)
	p-value			0.002	
Length of pen fences	< 80 m	54	30 (55.6)		24 (19.6)
	≥ 80 m	62	12 (44.4)		50 (80.6)
	p-value			< 0.0001	
Roofed pens	No	96	47 (83.9)		49 (65.3)
	Yes	35	9 (16.1)		26 (34.6)
	p-value			0.0273	
No. of goats and sheep	< 100	56	36 (75)		20 (27.1)
	≥ 100	66	12 (25)		54 (72.9)
	p-value			< 0.0001	

Table I. – Characteristics of domiciliary unit in the four agropastoral groups issued from the population surveyed.

Classification by	N	**Dwelling infestation with** ***T. brasiliensis*** N (%)	***T. pseudomaculata*** N (%)
Population categories			
Farmers	30	7 (23.33)	1 (3.33)
Casual workers	26	13 (50)	4 (15.38)
Exclusive breeders	35	16 (47.5)	6 (17.14)
Retired breeders	40	12 (30)	14 (35)
p-value		0.0984	0.0085
Peridomicile organisation			
Farmers & casual workers "(Small dwelling; few animals & corrals)"	56	20 (35.7)	5 (8.9)
Breeders exclusive & retired "(Large dwelling; many animals & corrals)"	75	28 (37.3)	20 (26.8)
p-value		0.8571	0.013
Way of life			
Farmers & retired breeders "(Less contact with caatinga; more settled)"	70	19 (27.14)	15 (21.43)
Casual workers & exclusive breeders "(More contact with caatinga; more mobile)"	61	29 (47.54)	10 (16.39)
p-value		0.0187	0.5103

Table II. – Distribution of *Triatoma* species according to the population surveyed.

cribed for a long time. By the fact that *T. brasiliensis* has adapted to the human environment and particularly to house in some regions, this species is considered as epidemiologically linked to human Chagas disease. On the other hand, large colonies of *T. pseudomaculata* are only formed in the peridomestic environment and, because this species is poorly adapted to the house, it is considered of secondary importance (WHO, 2002). Since the 16th century, the increasing rural populating and subsequent anthropic pressure by livestock farming have damaged the *caatinga*. In recent decades, irrigation projects along the São Francisco River have also attracted populations from Pernambuco and Ceara and promoted human settlement. The unfavorable environmental changes have resulted in the disturbance on triatomine silvatic ecology and led triatomines to move to peridomestic/domestic structures where they could find a variety of hiding places and food for forming colonies and growing (Schofield, 1994). The features of natural and artificial structures that provide refuge to Triatominae in the human environment were widely studied with the aim to quantify the risk factors for epidemiological diagnosis and optimize the control program activities (Cecere *et al.*, 1997; Salvatella *et al.*, 1998). On the other hand, the knowledge on the initial stage of triatomine invasion of the human environment is based on rough data. If the flight to light source of silvatic triatomines is considered as an important means of dispersal and invasion in Triatominae (Zeledon & Rabinovich, 1981; Schofield *et al.*, 1992, Vazquez-Prokopec *et al.*,2004) the role of human activities on the passive transport of insects from the silvatic environment to house is little-known (Coimbra, 1988; Walter, 2003).

In our area, the infestation rate of domiciliary units is twice higher with *T. brasiliensis* than with *T. pseudomaculata*. However, this apparent higher prevalence may be overestimated: whatever its stage, *T. brasiliensis* is a fast and colored insect and, also because of its colonies generally large, it is more easily detectable. Walter *et al.* (2004) suggest that infestation of domiciliary units with *T. pseudomaculata* is associated with the proximity of shrub plots. In areas where the *caatinga* has been heavily cleared through livestock or irrigation farming, the dwelling infestation with *T. pseudomaculata* significantly decreases. So, the farmers living in clearly areas near the river and practicing irrigated agriculture are less exposed than other groups to triatomine infestation. Among the three other groups that are homogeneously distributed throughout the *caatinga*, retired farmers are the most exposed to *T. pseudomaculata* infestation for a reason probably independent of environmental conditions. On the other hand, the four groups seem to be similarly exposed to the infestation with *T. brasiliensis*.

Considering the scale level of the domiciliary unit, previous studies have shown that *T. brasiliensis* and *T. pseudomaculata* occupy and share the same type of peridomestic ecotopes: brick and tiles pile, pen fence, chicken coop and other animal shelter (Costa *et al.*, 1998; Oliveira-Lima *et al.*, 2000; Diotaiuti *et al.*, 2000). Walter *et al.* (2004) have shown that the number and size of pens are risk factors for peridomestic infestation with both triatomine species, while the number of goats, cows and dogs significantly increases the risk of *T. pseudomaculata* infestation. The current study shows that the dwellings of farmers and casual workers are smaller, with few animals and are consequently less infested with *T. pseudomaculata* ($p < 0.05$). On the other hand, the *T. brasiliensis* infestation rate is not linked to any group of population and does not vary significantly according to the peridomestic and livestock size.

At level of triatomine microhabitats, some authors have noted that *T. pseudomaculata* and *T. brasiliensis* divide the same artificial ecotopes (Bento *et al.*, 1989; Sarquis *et al.*, 2004). At Curaça, we have observed that both species may share the same post fence or chicken coop (Carbajal de la Fuente *et al.*, unpublished data). The interspecific competition would always be favorable to *T. brasiliensis*, in regard of its shorter life cycle (Pinto Soares *et al.*, 2000). Consequently, *T. pseudomaculata* would infest the peridomestic structures located near shrub plots, which accumulate cattle and corrals and are not invaded by *T. brasiliensis*.

The mobility of population and its close contact with caatinga (casual workers and exclusive cattle farmers pooled) seem to favor the *T. brasiliensis* infestation of dwellings. These results rather support the hypothesis of *T. brasiliensis* passive transport by man or animal from its source (rocks) towards the dwellings. It is also possible that *T. brasiliensis* (or a semi-domesticated sub-population of *T. brasiliensis* as noticed by Costa *et al.*, 2002) is passively dispersed by men from one house to another. Field experiments of light trapping, showing that *T. brasiliensis* is not considered a good flyer compared with *T. pseudomaculata* (Carbajal de la Fuente *et al.*, in press), support this hypothesis. In this context, the passive introduction of triatomines by the most mobile groups would strongly favour the installation of the more competitive *T. brasiliensis* inside the peridomicile.

By the environmental changes which result of its agro-pastoral activities, the man is responsible for the disturbance of the triatomine silvatic ecology. By its behavior, the man may also facilitate the triatomine intrusion into the household. So, this study gives indication of its direct involvement in the dispersal of insects through its moving throughout the *caatinga*, and in the first stage of dwelling invasion. Then the characteristics of the dwelling and organization of annexes (location, substrate, sort, presence of animals) will allow or not the colonization by the vector. Finally, the inter-spe-

cific competition will favor one species over the other. Control measures against triatomine infestation have not to focus only on peridomiciliar organization but have also to take into account the bio-ecology of local species and human activities that favor the intrusion of vectors inside the peridomestic areas. Insecticide spraying and house improvement were effective for the elimination of the exogenous *T. infestans*. On the other hand, a better understanding of human behaviors that favor the triatomine peridomestic infestation is required to provide advice for human communities in order to reduce the incursion of silvatic vectors. A better understanding of the peridomestic ecology of vectors and interspecific competition for colonizing ecotopes is also required.

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