Effectiveness of residual spraying of peridomestic ecotopes with deltamethrin and permethrin on *Triatoma infestans* in rural western Argentina: a district-wide randomized trial

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Objective To compare the effectiveness of a single residual spraying of pyrethroids on the occurrence and abundance of *Triatoma infestans* in peridomestic ecotopes in rural La Rioja.

Methods A total of 667 (32.8%) peridomestic sites positive for *T. infestans* in May 1999 were randomly assigned to treatment within each village, sprayed in December 1999, and reinspected in December 2000. Treatments included 2.5% suspension concentrate (SC) deltamethrin in water at 25 mg active ingredient (a.i.)/m^2 applied with: (a) manual compression sprayers (standard treatment) or (b) power sprayers; (c) 1.5% emulsifiable concentrate (EC) deltamethrin at 25 mg a.i./m^2; and (d) 10% EC *cis*-permethrin at 170 mg a.i./m^2. EC pyrethroids were diluted in soybean oil and applied with power sprayers. All habitations were sprayed with the standard treatment.

Findings The prevalence of *T. infestans* 1-year post-spraying was significantly lower in sites treated with SC deltamethrin applied with manual (24%) or power sprayers (31%) than in sites treated with EC deltamethrin (40%) or EC permethrin (53%). The relative odds of infestation and catch of *T. infestans* 1-year post-spraying significantly increased with the use of EC pyrethroids, the abundance of bugs per site before spraying, total surface, and host numbers. All insecticides had poor residual effects on wooden posts.

Conclusion Most of the infestations probably originated from triatomines that survived exposure to insecticides at each site. Despite the standard treatment proving to be the most effective, the current tactics and procedures fail to eliminate peridomestic populations of *T. infestans* in semiarid rural areas and need to be revised.

Keywords Pyrethrins/administration and dosage; Triatoma/drug effects; Insect control/methods; Randomized controlled trials; Argentina (*source: MeSH, NLM*).

Mots clés Pyréthrine/administration et posologie; Triatoma/action des produits chimiques; Lutte contre insecte/méthodes; Essai clinique randomisé; Argentine (*source: MeSH, INSERM*).

Palabras clave Piretrinas/administración y dosificación; Triatoma/efectos de drogas; Control de insectos/métodos; Ensayos controlados aleatorios; Argentina (*fuente: DeCS, BIREME*).

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Voir page 203 le résumé en français. En la página 204 figura un resumen en español.

Introduction

Triatoma infestans, the main vector of Chagas disease, has been the target of the regional elimination programme "Southern Cone Initiative" since 1991 (*1*). Based mostly on the residual application of pyrethroid insecticides, this programme has been much more successful in Brazil, Chile, and Uruguay, than in the semiarid Chaco extending over Argentina, Bolivia, and Paraguay. Resurgence of peridomestic *T. infestans* populations after spraying with pyrethroids has frequently been reported by official control programmes in Argentina (S. Blanco, unpublished data, 2000), but the reasons remain unclear. Pyrethroids have proven much more effective in human habitations (*2*, *3*) than in peridomestic ecotopes housing domestic animals and various species of triatomine bugs (*4–10*).

The formulation of the insecticide affects its residual activity (*2*). For example, emulsifiable concentrate (EC) cyfluthrin had a greater impact on sand flies that rested on sylvatic vegetation, probably because the oil carrier allowed a greater adsorption of the insecticide to the substrate (*11*). In addition, we hypothesized that newer formulations of EC pyrethroids applied with back-pack power sprayers might have greater effect than wettable powder (WP) or suspension concentrate (SC) formulations applied with manual sprayers, because

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power sprayers might increase the penetration of insecticides into deep refuges and provide a greater initial impact (*3*). EC or WP deltamethrin suppressed peridomestic infestations by *T. infestans* for 500 days (*4*), though not always (*8*). Our objectives were to compare the effectiveness on peridomestic populations of *T. infestans* of new emulsifiable formulations of deltamethrin and *cis*-permethrin applied with power sprayers relative to that of SC deltamethrin applied with manual sprayers (the standard treatment) or motor sprayers in a district-wide infested area. We also sought to identify factors that modify the local effectiveness of pyrethroids.

Methods and materials

Study area

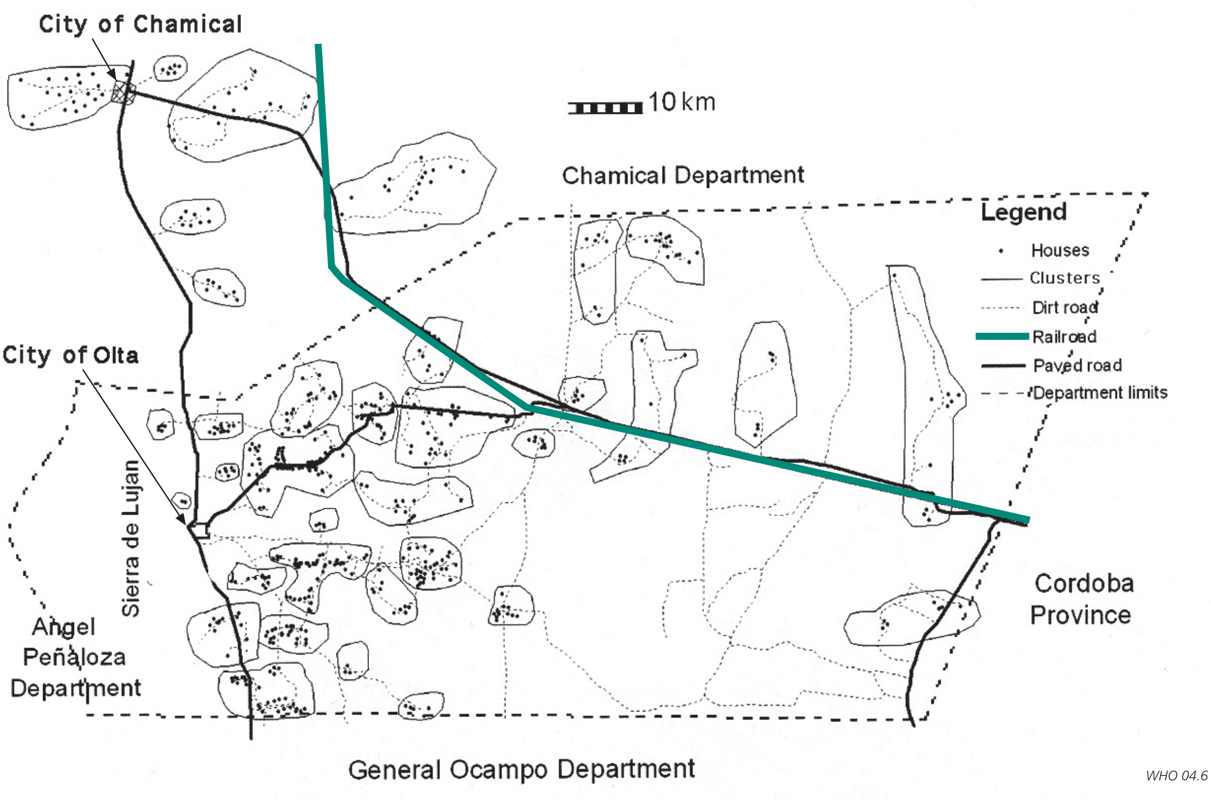
The study was conducted in rural areas around Olta (30.4ºS, 66.1ºW), Departments General Belgrano and Chamical, Province La Rioja, Argentina (Fig. 1). The area is on a semiarid plain with xerophytic vegetation, and has been described elsewhere (*12*). The houses had last been sprayed with beta-cyfluthrin approximately 5–6 years before this trial. Most houses were of adobe bricks and thatched roofs, and nearly all had numerous typical peridomestic structures (range, 1–10 per house), for domestic animals (*10*). The area was selected because it had shown recurrent reinfestation after insecticide spraying and high peridomestic infestation rates; most houses were relatively easy to access, and local authorities were cooperative. The study area was extended to adjacent areas of Chamical to reach about 100 houses per treatment.

Study design

The trial was divided into a baseline survey, intervention, and assessment. At baseline, three teams numbered all 369 houses with a metal plaque (Fig. 1), and surveyed 362 houses between 22 April and 20 May 1999. Each team was composed of two highly experienced bug collectors from the National Vector Control Programme (NVCP) staff, one bug collector from the local control programme, and one supervisor. Supervisors explained the objectives and phases of the trial to every household, and canvassed each family head to record the number of residents, type and number of domestic animals, and use of insecticides (type and frequency of use). The number and type of domestic and peridomestic structures were sketched on a map, building materials were noted, and distances from each structure to human habitations were paced out. Two highly experienced NVCP bug collectors concurrently assessed the intensity of peridomestic infestation by *T. infestans* and other triatomine species using timed manual collections with an irritant spray (0.2% tetramethrin, Icona, Buenos Aires) for 30 min per house (*10*). The local bug collector searched for bugs in domestic areas. All bugs were examined in the field laboratory to determine numbers by species and stage (*10*).

The interventions aimed at full coverage (blanket spraying) and were carried out between 29 November and 23 December 1999, when the mean ambient temperature was 23.3 ºC (average minimum, 8.3 ºC; average maximum, 38.4 ºC). All houses were listed alphabetically by village and randomly assigned to a treatment within every village. Peridomestic sites were sprayed with 2.5% SC deltamethrin (K-Othrina, Agrevo, at 25 mg active ingredient (a.i.)/m^2) in water applied with (a) 5-litre manual compression sprayers with Teejet 8002 fan nozzles, considered the standard treatment, or (b) back-pack power sprayers of 15-litre capacity (Guarany, Brazil); (c) 1.5% EC deltamethrin (Cislin, Agrevo, at 25 mg a.i./m^2), and (d) 10% EC *cis*-permethrin (Chemotecnica, Buenos Aires, at 170 mg a.i./m^2), both applied with the back-pack power sprayers. All domestic

Fig. 1. **Sketch of the study area showing the location of houses and clusters in May 1999**



sites were sprayed with the standard treatment (*4*). EC-based pyrethroids were diluted in soybean oil to exclude the possibility that local alkaline waters might reduce their insecticidal activity. To prevent bias, EC insecticides were transferred from the original containers labelled by the manufacturer into 5-litre clean containers identified by a two-letter and two-number code, following criteria used in randomized trials (*13*). Two people not involved in the trial labelled the containers and stored the codes in duplicate.

All domestic and peridomestic sites were sprayed by four fixed teams, the members of which had no background information regarding the intensity of infestation in each site. Each team was composed of a highly experienced NVCP sprayman who only treated peridomestic sites, two local spraymen who only treated domestic habitats, and one supervisor. A total of 352 houses were sprayed, including 22 houses that could only be accessed in March 2000 and were sprayed with the standard treatment. A total of 17 houses, including three with infested peridomestic sites, remained unsprayed due to householders' absence or inaccessible dirt roads.

Before starting spraying operations, the discharge volume per minute of every power sprayer fitted with each type of plastic nozzle tip was measured three times using water and soybean oil. To keep the codes closed and to simplify spraying operations, we mixed 400 ml of EC insecticides with 6.6 litres of soybean oil. Nozzle tips No. 1 were used during the first week, but they frequently clogged and discharged small amounts of aerosol. We replaced them with nozzle tips No. 3 in the second week, but the rate of consumption of oil and the drop size were large. Therefore, nozzle tips No. 2 were used from the third week on. To keep the target dose, the spray coverage speed was readjusted according to the nozzle tip-specific discharge volume per minute. The applied insecticide dose in a daily sample of each team's sprays was estimated by measuring the area of each structure, the time used to spray it, and the volume of insecticide applied per site.

At 7 or 11 days post-spraying, sets of three replicates of 5–10 fifth instar nymphs totalling 163 *T. infestans* were exposed to cement blocks from four storerooms and wooden posts from four goat corrals under the shade. To fit to irregular surfaces, the insects were held in cones (10 cm in height and 14 cm in diameter) made of X-ray developed film, which were attached to the substrate using nails and adhesive tape. After a 24-h exposure, the insects were transferred to clean jars containing folded filter paper and kept at 25–30 °C and 50–70% relative humidity. Mortality and knockdown effects were evaluated at 0, 1, 2, 3, 7, 14, 30, and 75 days post-exposure. The bugs were fed once on chicken at 30 days post-exposure. A second set of bioassays had to be entirely discarded because many of the insects reached the field in bad condition.

The assessment of intervention effects only included houses with peridomestic sites positive for *T. infestans* before spraying, and was carried out by four teams between 1 and 23 December 2000. Each team was composed of one supervisor and the two bug collectors who conducted the baseline inspections; the latter had no information regarding the insecticide used in each house. Bug collectors searched for triatomines in each peridomestic site positive before spraying using 0.2% tetramethrin for 15 min, and in a sample of the previously negative sites most likely to be infested, for a maximum of 40 min per house. Evaluations comprised 325 houses; these included 799 peridomestic sites randomly treated with insecticides in December 1999 and 61 sites sprayed in March 2000. Many sites positive at baseline could not be reinspected or were excluded because of lack of access to the house, disappearance, or physical modification. The collected bugs were processed as in the baseline survey. Infestation was taken to mean the capture of at least one live or moribund *T. infestans* of any stage (except eggs) in a given site. Colonization meant the finding of at least one live or moribund *T. infestans* nymph, regardless of the presence of other stages or triatomine species. Abundance referred to the number of live or moribund *T. infestans* bugs captured per peridomestic site over a defined search period.

Data analysis

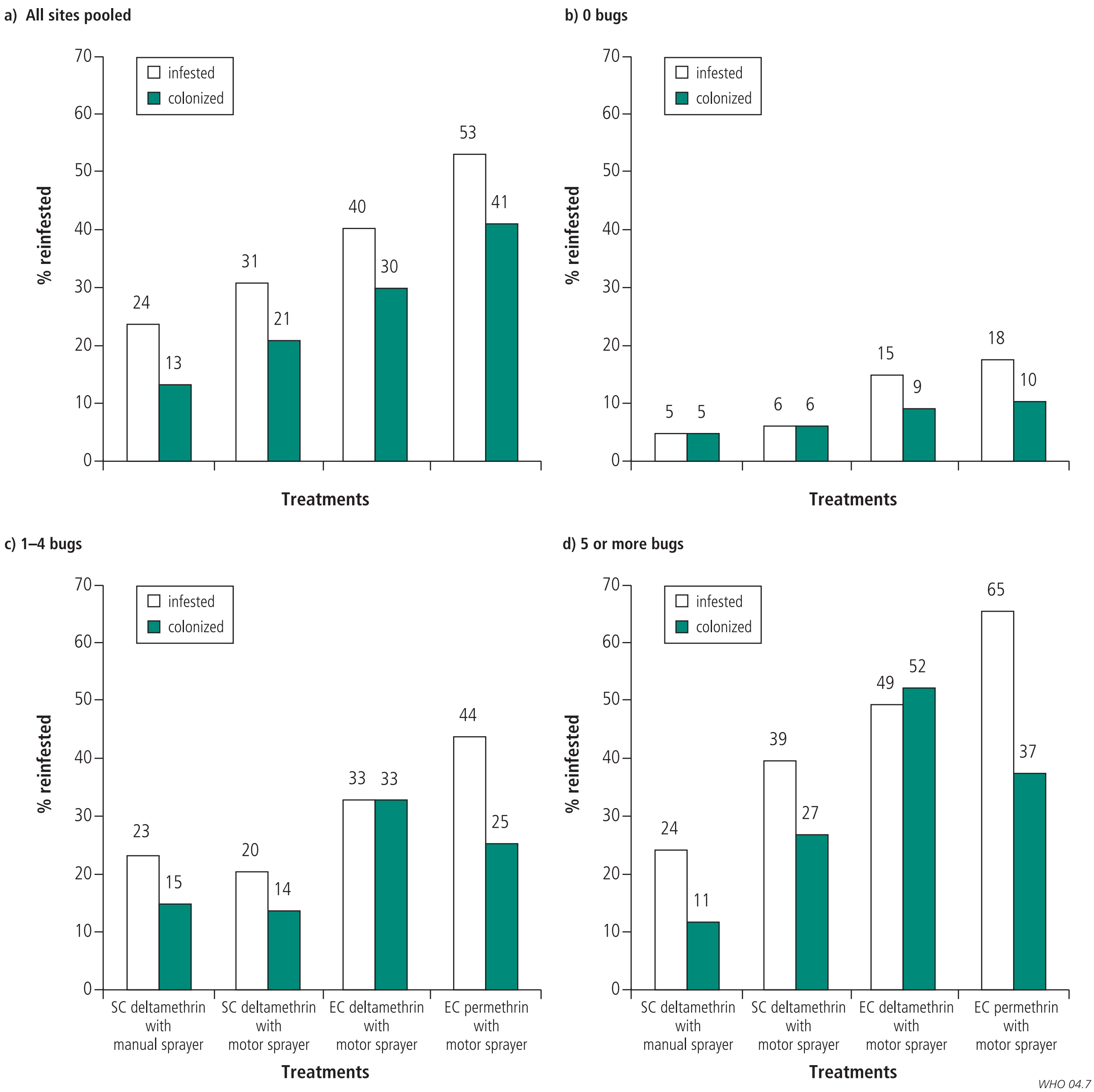
The unit of analysis was the peridomestic site infested by *T. infestans* at baseline, randomly assigned to an insecticide treatment and sprayed in December 1999, and reinspected 1-year post-spraying. Six such sites with missing data were excluded from regression analyses, which were based on 513 sites. For analytical purposes, the houses were tentatively grouped into 35 clusters according to a minimum distance between adjacent clusters (2 km), and the degree of connectivity among houses within a given cluster (Fig. 1). The outcome variables were: (a) the proportion of sites infested by *T. infestans* 1-year post-spraying, analysed by logistic-binomial random effects regression for distinguishable data (*14*); and (b) the log-total number of *T. infestans* collected per site 1-year post-spraying, analysed by multiple linear regression. The explanatory variables were insecticide treatment (four levels, with SC deltamethrin applied with manual sprayers as the reference level); log-number of *T. infestans* in site i before spraying; spray team (four levels); opportunity (or week) of treatment (three levels); type of peridomestic ecotope (two levels, representing roofed structures, such as storerooms or sheds or kitchens, versus unroofed structures, such as corrals and piles); and surface and reported number of domestic animal hosts in each site, transformed to log ($x + 1$). Statistical significance was judged at the 5% level. Interactions between significant predictors were added stepwise one by one and kept in the model if they proved significant. The survival of bugs used in bioassays was analysed using Gehan's generalized Wilcoxon test.

Results

A total of 5251 *T. infestans* bugs were collected from 667 (38.2%) of 1748 peridomestic sites inspected at baseline (mean, 2.1 infested sites and 1.8 colonies per house). At a household level, the prevalence of peridomestic *T. infestans* decreased from 90.1% at baseline to 70.5% 1-year post-spraying. Sites treated with SC deltamethrin and manual sprayers showed the lowest prevalence of *T. infestans* 1-year post-spraying (24%), followed by those treated with SC deltamethrin (31%), EC deltamethrin (40%), and EC permethrin (53%) applied with power sprayers (Fig. 2 a)). The percentage of colonization by *T. infestans* showed a similar pattern as infestation but with slightly lower rates.

Infestation rates 1-year post-spraying increased markedly with the abundance of *T. infestans* per site before spraying (Fig. 2 b)–d)). In peridomestic sites with 0 or 1–4 bugs per site at baseline, both SC deltamethrin-based treatments presented lower infestation rates (5–6% and 20–23%, respectively) than EC-based treatments (15–18% and 33–44%, respectively) (Fig. 2 b) and Fig. 2 c)). In sites with five or more bugs before spraying, SC deltamethrin achieved a lower infestation rate when applied with manual rather than power sprayers (24% versus 39%), and both were more effective than EC-based treatments (49–65%) (Fig. 2 d)).

Fig. 2. **Percentage of infestation or colonization with *Triatoma infestans* 1-year post-spraying according to the abundance per site before spraying in peridomestic sites treated with suspension concentrate (SC) deltamethrin applied with manual or power sprayers, and emulsifiable concentrate (EC) deltamethrin or EC permethrin applied with power sprayers in the study area in December 1999**



At baseline, the prevalence of infestation by *T. infestans* peaked in goat or sheep corrals (70%), followed by storerooms or sheds (51%), chicken coops (46%), and kitchens (42%) (Table 1). One year post-spraying, goat or sheep corrals showed the largest mean infestation rate (57%), followed by chicken coops (33%), storerooms or sheds (28%), and pig pens (25%). Goat or sheep corrals represented 44% of all the infested, sprayed, and reinspected sites, but they contributed to 68% of the infestations detected.

Using multiple logistic regression, the relative odds of infestation 1-year post-spraying differed in a highly significant way among treatments but not between those based on SC deltamethrin (Table 2). The successive addition of the log-number of *T. infestans* per site before spraying, log-total surface, and log-number of domestic hosts improved the fit of the model in a highly significant way, whereas the spray team, treatment opportunity, and type of ecotope exerted no significant effects on the likelihood of infestation. Addition of the random parameter measuring household clustering effects improved the fit significantly ($P = 0.008$). Only the interaction between treatment and bug abundance before spraying was statistically significant. Logistic regression results were qualitatively similar when all 799 peridomestic sites were included in the analysis.

The relative reductions of *T. infestans* abundance 1-year post-spraying achieved by SC deltamethrin applied with manual (76.1%) or power sprayers (76.4%) were significantly greater than those achieved by EC deltamethrin (62.6%) or EC permethrin (48.7%) (Table 3). Median *T. infestans* catches per infested site 1-year post-spraying increased from 2 bugs for SC deltamethrin (first-third quartiles, Q1–Q3, 1–6 bugs) to 5 (1–8)

Table 1. **Percentage relative reduction of the mean abundance of *Triatoma infestans* per site 1-year post-spraying in infested peridomestic sites randomly treated with SC deltamethrin applied with manual or power sprayers, or EC deltamethrin and EC permethrin applied with power sprayers in December 1999; Belgrano and Chamical, La Rioja**

Treatment	Number of infested sites sprayed	GMR of bug abundances[a]	SE[b]	Mean per cent reduction	95% confidence interval
SC[c] deltamethrin, manual sprayer	122	-0.6218	0.0909	76.1	71–81
SC deltamethrin, power sprayer	130	-0.6279	0.0765	76.4	72–80
EC[d] deltamethrin, power sprayer	138	-0.4276	0.0906	62.6	54–70
EC permethrin, power sprayer	129	-0.2896	0.0945	48.7	36–59

[a] Log_{10} (bug abundance in site *i* 1 year post-spraying + 1 / bug abundance in site *i* at baseline + 1). The antilogarithm of the geometric mean ratio (GMR) multiplied by 100 estimates the per cent relative reduction of abundance 1-year post-spraying.
[b] SE = standard error.
[c] SC = suspension concentrate.
[d] EC = emulsifiable concentrate.

Table 2. **Prevalence of peridomestic infestation with *Triatoma infestans* at baseline (April–May 1999) and 1-year post-spraying according to type of ecotope in infested peridomestic sites randomly treated with SC deltamethrin applied with manual or power sprayers, or EC deltamethrin and EC permethrin applied with power sprayers in December 1999; Belgrano and Chamical, La Rioja**

Ecotope	% Infested		% Infested 1-year post-spraying							
			SC[a] deltamethrin applied with							
	At baseline		Manual sprayer		Motor sprayer		EC[b] deltamethrin		EC permethrin	
Goat or sheep corral	70	(373)[c]	42	(50)	51	(57)	60	(58)	72	(61)
Storeroom or shed	51	(248)	17	(23)	11	(27)	43	(23)	42	(24)
Chicken coop	46	(158)	7	(14)	31	(13)	44	(16)	50	(12)
Kitchen	42	(124)	7	(15)	0	(7)	0	(7)	30	(10)
Trees with chickens	10	(357)	0	(4)	17	(6)	0	(13)	40	(5)
Pig pen	17	(136)	40	(5)	33	(3)	25	(4)	13	(8)
Piled material	27	(79)	0	(1)	17	(6)	33	(3)	20	(5)
Horse corral	10	(41)	0	(5)	1	(5)	0	(8)	1	(2)
Orchard	29	(7)	0	(1)		(0)		(0)		(0)
Latrine	9	(47)		(0)	0	(2)	0	(2)		(0)
Mud oven	18	(17)		(0)	0	(2)	0	(1)		(0)
Nests	50	(8)	0	(2)		(0)		(0)		(0)
Ramada	60	(5)		(0)		(0)	100	(1)	0	(2)
Trees without chickens	14	(14)	0	(2)	0	(2)	0	(2)		(0)
Others	40	(134)		(0)		(0)		(0)		(0)
Total	**38**	**(1748)**	**24**	**(122)**	**31**	**(130)**	**40**	**(138)**	**53**	**(129)**

[a] SC = suspension concentrate.
[b] EC = emulsifiable concentrate.
[c] No. of sites inspected for infestation.

and 6 (3–11) bugs for EC deltamethrin and EC permethrin, respectively. Multiple linear regression of the log-number of *T. infestans* collected per site 1-year post-spraying identified the same set of significant predictors as logistic regression (data not shown) and, additionally, a highly significant interaction between surface and host numbers. The total bug catch increased significantly with both total surface and local number of hosts in unroofed ecotopes, but not in storerooms, sheds, or kitchens (Fig. 3).

The insecticidal activity of pyrethroids differed significantly on cement blocks ($\chi^2 = 3.63$; df = 3; $P < 0.0001$) but not on wooden posts ($\chi^2 = 2.99$; df = 3; $P > 0.3$) (Fig. 4). SC deltamethrin killed all the insects exposed to sprayed cement blocks, but none of the nymphs exposed to wooden posts. Bug survival at 75-days post-exposure to EC pyrethroids was very high both on wooden posts (73–80%) and cement blocks (63–73%). The surviving bugs were able to feed and most reached the adult stage.

Discussion

The standard treatment proved to be the most effective, but it failed to eliminate *T. infestans* in peridomestic sites just 1-year post-spraying. The ranking of treatment effectiveness was robust to changes in nozzle tips during the trial, spray team composition, treatment opportunity, types of regression analysis, and outcome variables. The estimates of the relative reduction in bug abundance actually underestimated the true impact of all insecticides because baseline collections were conducted when *T. infestans* populations and temperatures were decreasing (mid-autumn), whereas the post-spraying evaluation was carried out when bug populations were increasing and their flushing-out response to the irritant spray was enhanced (early summer). Considering effectiveness, cost, need of fuel, and low acceptability by spraymen, power sprayers did not provide any net benefit relative to manual sprayers in the control of *T. infestans* in peridomestic ecotopes. Randomization of treatments within clusters of houses and blind assessment procedures are distinctive features of this large-scale trial.

Residual foci

Several pieces of evidence clearly suggest that most of the infestations originated from triatomine bugs that survived exposure to the insecticides at each site (i.e. residual foci). First, the short-lasting residual effects of pyrethroids in peridomestic sites was well below the time taken for *T. infestans* eggs to hatch (range, 8–21 days) at local ambient temperatures (*15*). Marked exposure to sunlight and high temperature induce photolysis of pyrethroid molecules and thus reduce insecticidal activity (*8*). Additionally, power sprayers lifted dust that eventually would deposit on the sprayed surface and mask the insecticide. Second, a large fraction of all foci were high density and included late-instar nymphs. These instars, which may survive 1 year under fasting conditions and take 3–6 months to develop from eggs depending on local temperatures and host availability (*15*), have lower susceptibility to pyrethroids than younger instars (*16*). Third, the spatial distribution of foci 1-year-post-spraying was apparently equally widespread over the whole district. Fourth, the effectiveness of peridomestic treatments was modified by the abundance of *T. infestans* per site before spraying, as observed in another semiarid rural area (*17*, *18*). The greater the abundance of bugs during their egg-laying season, the greater the likelihood that some of the late-instar nymphs or eggs inside crevices or hollow logs would emerge after the insecticides' residual effects waned and initiate a new generation. Clearly, the effectiveness of pyrethroids on triatomine bug populations is bug-density dependent.

Peridomestic foci of *T. infestans* detected just 1–3 months after applying SC pyrethroids with manual sprayers (*5–8*, *18*) were most probably residual foci, but molecular methods are needed to provide conclusive evidence regarding the source of reinfestants. Other sources of reinfesting bugs were much less likely in our study. The likelihood of invasion by *T. infestans* by flight or passive transport from adjacent untreated areas was extremely unlikely given the large spraying coverage (95%). In the past, sylvatic colonies of *T. infestans* in semiarid rural Argentina were very rarely found despite intensive searches (*15*). The significant effects of household clustering on the likelihood of infestation suggests that a fraction of all foci detected 1-year after spraying might have originated from *T. infestans* dispersing by flight from nearby sites treated with the least effective treatments, or from other unidentified cluster-specific attributes.

Table 3. **Results of random-effects multiple logistic regression of the odds of infestation 1-year post-spraying in 513 peridomestic sites infested at baseline and randomly treated with insecticides in December 1999; Belgrano and Chamical, La Rioja**

Variables	Levels[a]	Coefficient	SE[b]	*P*	Odds ratio	Lower limit	Upper limit
Intercept		-3.165	0.568	<0.001	0.04	0.01	0.13
Treatment[c]	SC[d] deltamethrin with power sprayer	0.345	0.327	0.29	1.41	0.74	2.68
	EC[e] deltamethrin with power sprayer	0.795	0.318	0.01	2.21	1.19	4.13
	EC permethrin with power sprayer	1.390	0.320	<0.001	4.01	2.14	7.52
Log-number of *Triatoma infestans* per site before spraying[c]		0.651	0.224	0.004	1.92	1.24	2.97
Log-total surface		0.745	0.196	<0.001	2.11	1.43	3.09
Log-number of hosts		0.760	0.183	<0.001	2.14	1.49	3.06
Treatment week	2	-0.271	0.448	0.54	0.76	0.32	1.83
	3	-0.542	0.417	0.19	0.58	0.26	1.32
Spray team	2	0.161	0.394	0.68	1.17	0.54	2.54
	3	-0.107	0.363	0.77	0.90	0.44	1.83
	4	0.115	0.379	0.76	1.12	0.53	2.36
Random effects parameter[f]		0.497	0.183				

[a] Reference levels: for treatment, SC deltamethrin with manual sprayers; for ecotope, storeroom or shed, or kitchen (roofed structures); for treatment week, first week; and for spray team, team number 1.
[b] SE = standard error.
[c] Interaction between treatment and log-number of *T. infestans* before spraying was significant.
[d] SC = suspension concentrate.
[e] EC = emulsifiable concentrate.
[f] For the most parsimonious fitted model, likelihood ratio statistic = 5.705, deviance 546.47, *df* = 500, $P < 0.001$.

Fig. 3. **Plots showing polynomial smoothing of the total number of *Triatoma infestans* collected per peridomestic site 1-year post-spraying according to total surface and number of hosts in a) unroofed and b) roofed ecotopes in the study area December 1999.** All data were transformed to log (χ + 1). All treatments pooled

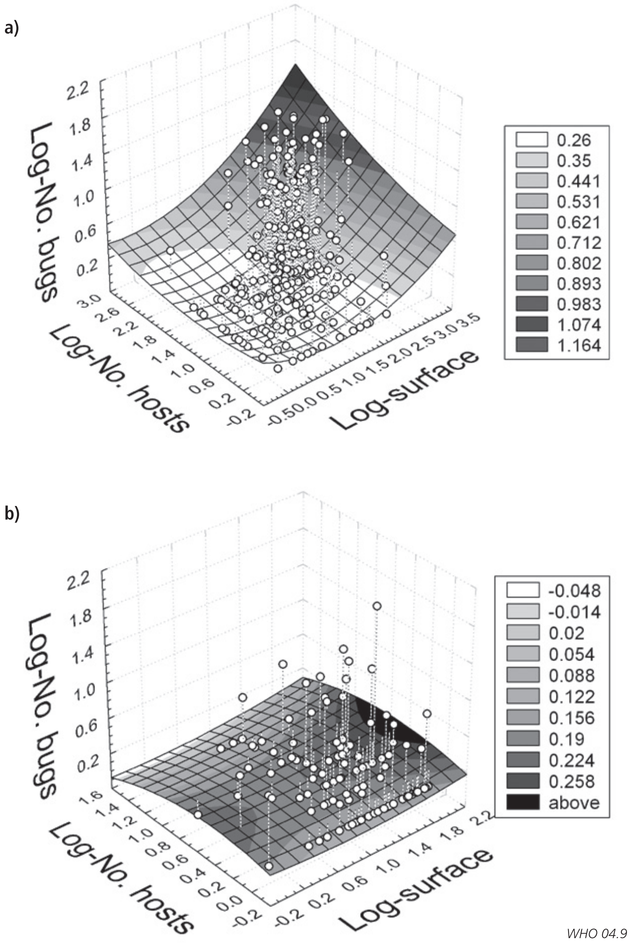
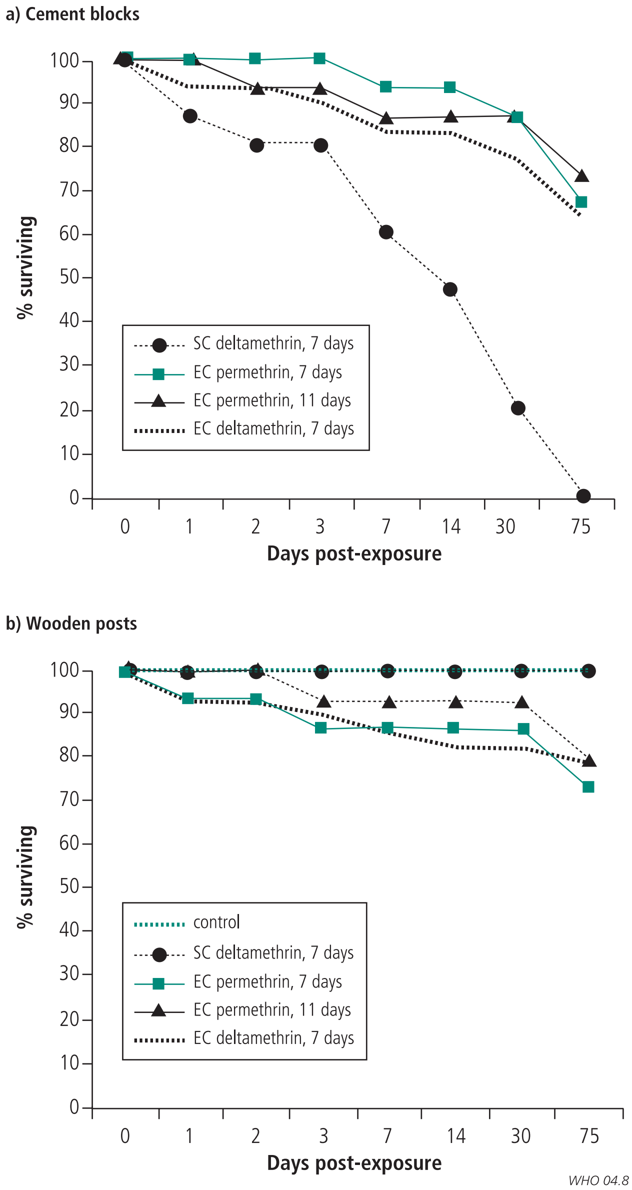


Fig. 4. **Survival of laboratory-reared fifth instar nymphs of *Triatoma infestans* following exposure to wooden posts and cement blocks sprayed with suspension concentrate (SC) deltamethrin, emulsifiable concentrate (EC) deltamethrin or EC permethrin 7–11 days beforehand**



The small percentage of infested sites found among those that had been negative before spraying may be explained by the limited sensitivity of the capture method in peridomestic sites (*19*), or by new colonizations that occurred between the baseline survey in May and interventions in December. Because *T. infestans* collected from 14 villages in our study area were fully susceptible to pyrethroids (*20*), resistance cannot explain the low degree of effectiveness of the tested pyrethroids in peridomestic sites.

Comparison with other studies

At a household level, peridomestic infestation rates 1-year post-spraying were much greater than those recorded using the same insecticides, doses, and qualified staff in other semiarid rural areas (*4–7*, *18*). As these trials were conducted under cooler temperatures (in May–October) than ours, the observed variation in effectiveness may be related to the inverse temperature-dependence of the insecticidal activity of pyrethroids (*8*). This important factor has seldom been considered and is especially relevant for peridomestic ecotopes (*21*). It is noteworthy that the ranking of post-treatment infestation of peridomestic ecotopes matched their lack of capacity to damp temperature fluctuations, which increased from goat corrals to storerooms and human habitations (*21*). The joint effects of temperature, exposure to sunlight and dust, and type of substrate in field operations will very likely predominate over small variations in effectiveness among insecticides determined in laboratory settings.

SC pyrethroids showed highly variable (1–12 months) residual activity against *T. infestans* on indoor porous or mud walls protected from sunlight (*4*, *5*, *22*, *23*), but we failed to find any data for peridomestic structures. Although our bioassays were limited, the average residual effects of the insecticides were consistent with their ranking of effectiveness. Moreover, the very poor residual effects of all pyrethroids on exposed wooden posts were consistent with the high rates of infestation observed before and after the blanket spraying, especially in such corrals. Typically made of wooden posts, hollow logs, and piled branches of thorny scrub in semiarid regions, goat or sheep corrals provide abundant refuges for the bugs and host a sizable number of animals year-round. Both refuge and host availability significantly increased the population abundance and growth rate of *T. infestans* in experimental huts under natural climatic conditions (*24*, *25*). Consistent with this evidence, our trial is the first to show that the joint effects of type of material, total surface, and host numbers modify the likelihood of local infestation and abundance of *T. infestans* in peridomestic sites after spraying with pyrethroids. Clearly, the study goat or sheep corrals are key sites for maintaining residual populations of *T. infestans* after insecticide spraying.

Conclusion

The difficulty of eliminating *T. infestans* from heavily treated areas in the semiarid Chaco may be explained by the joint effects of high-density infestation, numerous peridomestic structures with materials that provide refuges for the bugs, high temperature, exposure to sunlight and dust, and probably inappropriate insecticide application dosages, frequency, and timing. The spray coverage and surveillance of sparsely populated, impoverished rural areas with frequent migration is complex and also contributes to persistent infestations. Blanket or selective insecticide sprays are frequently conducted during the hot season, when triatomine bugs increase in numbers and become more apparent, but unfortunately under these conditions the effectiveness of pyrethroid sprays is strongly reduced. The remedial nature of such actions is enhanced in community-based control programmes against *T. infestans* because rural villagers do not perceive peridomestic infestations as a direct nuisance or hazard to their animals or themselves. Early and persistent peridomestic infestation after spraying with the standard treatment against *T. infestans* (*4–6*, *8*), *Triatoma brasiliensis*, and *Triatoma pseudomaculata* in Brazil (*9*, *26*), and *Triatoma pallidipennis* in Mexico suggests that this may be a generalized problem in arid or semiarid areas, although reinfestations by several species other than *T. infestans* may also be driven by invasion from sylvatic foci. The evidence herein provided demonstrates that the current tactics and procedures fail to eliminate peridomestic populations of *T. infestans* in semiarid rural areas and need to be revised. Until more cost-effective and environmentally friendly tools become available, triatomine control programmes may improve the use of available or related SC pyrethroids using specific tactics tailored to the peridomestic environment. This would include determination of optimal dosages, frequency, and timing of insecticide spraying; reinforced surveillance of key peridomestic sites using simple sensing devices (*12*); and development of environmental management methods aimed at reducing bug abundance in key structures housing domestic animals (*2*). ■

Conflicts of interest: none declared.

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Résumé

Efficacité sur *Triatoma infestans* de la pulvérisation des écotopes péridomestiques par la deltaméthrine et la perméthrine rémanentes dans un district rural de l'ouest de l'Argentine : essai randomisé de district

Objectif Comparer l'efficacité d'une pulvérisation rémanente unique de pyréthrinoïdes sur la présence et l'abondance de *Triatoma infestans* dans les écotopes péridomestiques du district rural de La Rioja.

Méthodes Un total de 667 sites péridomestiques (soit 32,8 %) où la présence de *T. infestans* avait été décelée en mai 1999 ont été tirés au sort dans chacun des villages pour être traités; la pulvérisation a eu lieu en décembre 1999, et ils ont été de nouveau inspectés en décembre 2000. Le traitement était le suivant : suspension concentrée à 2,5 % de deltaméthrine dans l'eau, épandue à la dose de 25 mg de substance active /m^2, appliquée au moyen : a) d'un pulvérisateur à pression préalable actionné manuellement (traitement classique) ou b) d'un pulvérisateur à moteur ; c) concentré émulsifiable à 1,5 % de deltaméthrine, épandu à la dose de 25 mg de substance active /m^2 ; d) concentré émulsifiable à 10 % de *cis*-perméthrine, épandu à la dose de 170 mg de substance active /m^2. Les concentrés émulsifiables de pyréthrinoïdes ont été dilués dans l'huile de soja et épandus au moyen de pulvérisateurs à moteur. Dans toutes les habitations l'épandage a été fait selon la méthode classique.

Résultats Un an après la pulvérisation, la fréquence de *T. infestans* était nettement plus faible dans les sites traités par la deltaméthrine en suspension concentrée appliquée manuellement (24 %) ou au moyen de pulvérisateurs à moteurs (31 %) que dans les sites traités par le concentré émulsifiable de deltaméthrine (40 %) ou de perméthrine (53 %). Un an après la pulvérisation, la probabilité relative d'infestation ou de capture de *T. infestans* était nettement augmentée par les facteurs suivants : utilisation d'une concentré émulsifiable de pyréthrinoïde, abondance des triatomes sur le site avant pulvérisation, surface totale et nombre d'hôtes. Tous les insecticides avaient peu d'effet rémanent sur les poteaux en bois.

Conclusion La plupart des infestations sont probablement dues à des triatomes qui ont survécu à l'exposition aux insecticides dans chacun des sites. Même si le traitement classique se révèle être le plus efficace, la stratégie et les méthodes actuelles ne parviennent pas à éliminer les populations péridomestiques de *T. infestans* en milieu rural semi-aride ; elles devront être révisées.

Resumen

Eficacia contra *Triatoma infestans* del rociamiento de acción residual de ecotopos peridomésticos con deltametrina y permetrina en zonas rurales del oeste de la Argentina: ensayo aleatorizado en un distrito

Objetivo Comparar la efectividad de un único rociamiento de acción residual de piretroides contra la presencia y abundancia de *Triatoma infestans* en ecotopos peridomésticos en La Rioja rural.

Métodos Un total de 667 (32,8%) sitios peridomésticos positivos para *T. infestans* en mayo de 1999 fueron asignados aleatoriamente a tratamiento dentro de cada aldea, rociados en diciembre de 1999, y reinspeccionados en diciembre de 2000. Las opciones de tratamiento fueron una suspensión concentrada (SC) de deltametrina al 2,5% en agua a razón de 25 mg ai/m^2 aplicada mediante: (a) pulverizadores manuales de compresión (tratamiento ordinario) o (b) pulverizadores eléctricos; (c) un concentrado emulsionable (CE) al 1,5% de deltametrina a 25 mg ai/m^2; y (d) un CE al 10% de *cis*-permetrina a 170 mg ai/m^2. Los CE de piretroides se diluyeron en aceite de soja y se aplicaron con pulverizadores eléctricos. Todas las viviendas se rociaron aplicando el tratamiento ordinario.

Resultados La prevalencia de *T. infestans* al cabo de un año del rociamiento fue significativamente menor en los sitios tratados con SC de deltametrina aplicada con pulverizadores manuales (24%) o eléctricos (31%) que en los sitios tratados con CE de deltametrina (40%) o CE de permetrina (53%). Las posibilidades relativas de infestación y captura de *T. infestans* al cabo de un año del rociamiento aumentaban sensiblemente con el uso de CE de piretroides, la abundancia de insectos por sitio antes del rociamiento, la superficie total y el número de huéspedes. Todos los insecticidas tuvieron un escaso efecto residual en los postes de madera.

Conclusión La mayoría de las infestaciones se debieron probablemente a triatominos que sobrevivieron a la exposición a los insecticidas en cada sitio. A pesar de que el tratamiento ordinario demostró ser el más eficaz, los procedimientos y tácticas actuales no logran eliminar las poblaciones peridomésticas de *T. infestans* en las zonas rurales semiáridas, y deberían por tanto ser revisados.

Arabic

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