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Evaluation of the effectiveness of three sticky traps to monitor four species of cockroaches (Hexapoda: Blattaria) with simulated use tests

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Abstract

Background. *Cockroaches are the pest of major concern for the disinfestation programs of the sanitary system in Italy. Hygienic-sanitary interest is linked to the role of mechanical vectors of pathogens and to their allergological potential. Sticky traps are the best tool to monitor the presence of these insects and several types of them are available on the market. In most of the cases the traps are not indicated for a given species, but, instead, generically for cockroaches. Domestic cockroaches differ in morphology, size and habits. Consequently, the effectiveness of the trap can change in relation to the target species.*

Materials and methods. *In this study three of the most employed traps in Italy were compared: the INDIA trap with and without its attractant tablet (hereafter mentioned as INDIA-A and INDIA-E, respectively), the ZAPI Simply trap and the CATCHMASTER Spider & Insect Glue trap. We chose the four most common species of cockroach (Blattodea) in Italy,* Blatta orientalis *(L.),* Periplaneta americana *(L.) (Blattidae),* Blattella germanica *(L.) and* Supella longipalpa *(F.) (Blattellidae). Each species of cockroach was tested separately inside arenas containing one of the traps. Each test (one species with one kind of trap) was replicated five times.*

Results and discussion. *The INDIA-A trap collected more cockroaches of every species, followed by the INDIA-E. The ZAPI trap caught less specimens of each species in respect to the INDIA traps, with the only exception of B. orientalis, for which the ZAPI trap caught more than the INDIA-E. The CATCHMASTER trap performed significantly less for all the species.* B. orientalis *was the species most abundantly caught by all traps, followed by* B. germanica*,* S. longipalpa *and* P. americana*. No significant difference was observed in the catch according to the developmental stage. In general, there was no particular predisposition of any trap to catch a particular species.*

Conclusions. *It is not possible to indicate a model of trap for each species of cockroach, but it is clear that different traps have different performances in terms of attractiveness and capture. Therefore, the choice of the trap affects the results of the monitoring, and as consequence, the evaluation of the infesting population of the pest.*

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Introduction

The word "cockroach" refers to over 4,000 species of insects belonging to the order Blattaria. Of these species, approximately 30 live in close association with humans (1). The hygienic-sanitary interest is linked to the role of mechanical vectors of pathogens (2-4) and to the allergological potential (5, 6).

The most widespread species in Italy are: the Oriental cockroach (*Blatta orientalis,* L.), the German cockroach (*Blattella germanica,* L.), the American cockroach (*Periplaneta americana,* L.) and the brown-banded cockroach (*Supella longipalpa,* F.) (7-9). These four species are distributed differently throughout the Italian peninsula (10, 11).

Blattella germanica and *S. longipalpa* are considered as "small cockroaches". The German cockroach is common all over the Italian territory (12) and is strictly linked to the food industry and coffee shops, restaurants, bakeries, hospital (12, 13) but also houses, in particular rooms where food is handled (e.g. kitchens, dining rooms, etc.). *Supella longipalpa* is a species of relative recent introduction and its distribution is currently widening (14). Reports of *S. longipalpa* in Italy are far less numerous than *B. germanica*, with which it often gets confused. The brown-banded cockroach more commonly infests houses and offices rather than stores and restaurants (14, 15). This cockroach colonizes furniture and the high interior fixtures of an environment (e.g., false ceilings, shelves, walls, etc.) (16).

Blatta orientalis and *P. americana* are called "large cockroaches". Both the Oriental and the American cockroaches live in very moist spaces like the sewage system, drainage systems and urban underground environments (17). These species of cockroach are not commonly found indoors but when the outside infestation reaches high levels or when external temperature drops, some of these individuals can be found in bathrooms (18) and kitchens (15). Both the Oriental cockroach and *P. americana* have been reported all over the Italian peninsula (11, 19-21), but *B. orientalis* more tolerates low temperatures (22) and is therefore common also in the northern part.

Disinfestation from cockroaches is the intervention of pest control most requested from the Italian Public Health Units, followed by rodents and mosquitoes (12). A monitoring plan to keep under control potential infestations in food industries, commercial enterprises and public buildings should be implemented (23) as also required by the legislation on food hygiene (e.g. European Regulations 852/2004) and voluntary certification standard (e.g. BRC and IFS).

Sticky traps are the best tool to monitor the presence of cockroaches (24) and in the case of low infestations they can represent an effective control tool (25). Sticky traps also reveal which species are in the environment and give an idea about the infestation level (23, 26). These kinds of traps are cheap and easy-to-use. They are employed by pest control companies, as well as by private citizens and researchers. Sticky traps are also suggested by the European Chemical Agency (ECHA) in field tests for biocidal products, to measure a cockroach population size before and after the application of the testing product (27).

Several types of sticky traps are available on the market. These traps are different in shape, color, number of openings, position of the glue surface and type of attractant. In most cases, traps are not specifically indicated for a target species but generically for "cockroaches", even though the four considered species differ in terms of morphology, size and habits. Consequently, the effectiveness of a trap can vary depending on the target species.

In this study, three of the most employed sticky traps in Italy were tested to separately

catch *B. germanica*, *B. orientalis*, *P. americana* and *S. longipalpa*. By doing so, it was possible to evaluate eventual differences in catch according to the species, so that traps can be used specifically for a particular species of cockroach.

Materials and Methods

The experiment was carried out at Entostudio s.r.l. facilities from November to December 2016.

Target insects (cockroaches)

Four species of cockroaches were employed: *B. orientalis, B. germanica*, *P. americana* and *S. longipalpa*. All the tested species are reared in colonies at the Entostudio laboratory since 2011. The colonies of *B. orientalis, S. longipalpa* and *P. americana* were derived from specimens collected in a field in the Veneto region (NE-Italy), while *B. germanica* was obtained from laboratory colonies from Germany. They are reared in 45 liters plastic boxes under laboratory standard conditions: temperature of 25 ± 1 °C, relative humidity (RH) 50 ± 5% and light–dark cycle of 12:12. Colonies are provided with food (cat biscuits and potatoes) *ad libitum* and cardboard shelters.

Traps

Three types of traps were compared: the INDIA trap (India, Industrie Chimiche S.p.A., Padua, Italy) with and without its own food bait tablet (hereafter mentioned as INDIA-A, i.e. the trap with its attractant tablet and INDIA-E, without attractant), the ZAPI Simply trap (ZAPI Expert S.r.l., Conselve, Padua, Italy) and the CATCHMASTER Spider & Insect Glue trap (AP&G Co. Inc., Brooklyn, NY 11232, USA) - the latter two with the attractant incorporated into the glue, as reported on the label. All the traps are made of cardboard.

The INDIA trap is a box with a trapezoidal section (base of 10.0 x 15.5 cm and 2.0 cm tall). It has four entryways, one per side; the two on the long sides have a slope of 45°. On the bottom of the trap, there is a sticky surface. This trap is sold together with a licorice-scented tablet, which has to be placed on the sticky surface as the attractant. The external surface is blue-and-yellow-colored and the interior is white (Fig. 1a).

The ZAPI trap has the same shape and size as the INDIA trap, with an external surface that is red-colored and the internal white. It contains a visible attractant, which is a red stripe on the glue board (Fig. 1b). The composition of the attractant is not explained on the label.

The CATCHMASTER trap has a rectangular section (6.0 x 9.0 x 1.3 cm) and is completely white. The vanilla-aromatized glue is spread on the entire inner surface of the trap (Figure 1c). This trap is registered to catch insects and spiders, and is also suggested for cockroaches. Since the CATCHMASTER trap is about half

Figure 1 - The traps. a) INDIA trap; b) ZAPI trap; c) two CATCHMASTER traps.

the size of the other traps, two adjacent CATCHMASTER traps were used for each replication.

Experimental design

The experiment was carried out using four round arenas, 1.0 m in diameter and 35.0 cm tall, covered with a nylon film on the top to prevent insects' escape. Each arena contained a: Petri dish (without cover) filled with water, shelter made of black cardboard, Petri dish (without cover) filled with ten cat biscuits (Vita-day croccantini mix, Conagit S.p.A., Città di Castello, Italy) and one of the tested traps. Water was placed in the center of the arena, while the shelter, the food and the trap were located 3 cm away from the wall, equidistant from each other. The gap between the trap and the wall was kept to prevent the occasional entrance of cockroaches into the trap; since cockroaches are thigmotactic (26), they could possibly walk along the arena's walls and enter the trap by chance if it was placed adjacent to the wall.

Arenas were placed in a room at a temperature of 25 ± 1 °C and a RH 50 ± 5%. Tests were carried out in the dark to avoid insects using the trap as a shelter when the light was on.

The four species of cockroaches were tested in different arenas with one kind of trap at a time. Each arena held 10 ♂♂, 10 non-gravid ♀♀ and 30 juvenis (neanid and nymph) of mixed stages. At the beginning, cockroaches were released into the arena, containing only water and the shelter, to give them time to acclimate. After five hours, the food and the trap were added. Cat biscuits were put in together with the trap, and not before, to avoid their sent saturating the air, concealing the smell of the attractant. About 16 hours after the introduction of the cockroaches, the traps were collected and the caught cockroaches counted. The cockroaches remaining in the arena were removed and not used in further testing.

At the end of each trial, the room was ventilated and the arenas were cleaned up to remove the smell and fecal material to avoid cockroaches following fecal trails (28). Shelters, water and food containers were changed for every trial.

Data analysis

Each test (one species with one kind of trap) was replicated five times. The difference among percentages of overall catches by each trap was screened using the chi-square test. The average numbers of specimens of the different cockroach species collected by each trap were compared using the Analysis of Variance (ANOVA), followed by the Tuckey's test for post-hoc comparison. The software used was SPSS for Windows, version 13.0. Finally, the last analysis checked if each typology of trap caught more ♂♂, or ♀♀ or juvenis (neanid and nymph). Data were normalized and tested with Analysis of Variance (ANOVA) followed by the Tuckey's test if normally distributed, or else with Kruskal Wallis test followed by a Dunn test. These statistical analyses were performed in R version 3.6.1.

Results

Each species of cockroach was caught more by the INDIA traps, particularly by the INDIA-A ($p<0.01$). After comparison, the CATCHMASTER trap showed the lowest performance with all species ($p<0.01$). The ZAPI trap caught less specimens of each species in respect to the INDIA traps (Fig. 2), with the only exception of *B. orientalis*, for which the ZAPI trap caught more than the INDIA-E (Tab. 1).

Blatta orientalis was the species most abundantly caught by all traps followed by *B. germanica*, *S. longipalpa* and *P. americana* (Fig. 3).

No significant difference in catch according to developmental stage was

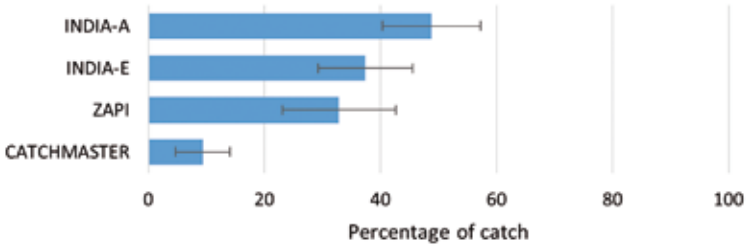

Figure 2 - Percentage of catch by each trap on the total of cockroaches released in the arenas. The value includes all species, all the life stages and both sexes, Bars represent Standard Error.

Table 1 - Comparison of the performance of catch per trap per species through the Analysis of Variance (ANOVA) followed by the Tuckey's post-hoc test.

Stage	Trap	Mean ± sd	•	F-value	P-value
Blattella germanica	INDIA-A	30.00 ± 4.74	a	23.17	<0.01
	INDIA-E	24.20 ± 7.66	ab		
	ZAPI	17.60 ± 3.78	b		
	CATCHMASTER	5.00 ± 2.00	c		
Blatta orientalis	INDIA-A	33.00 ± 4.80	a	30.35	<0.01
	INDIA-E	27.00 ± 4.74	a		
	ZAPI	29.40 ± 3.58	a		
	CATCHMASTER	11.20 ± 1.64	b		
Periplaneta americana	INDIA-A	15.20 ± 5.45	a	13.94	<0.01
	INDIA-E	10.20 ± 3.03	ab		
	ZAPI	6.40 ± 1.82	bc		
	CATCHMASTER	1.80 ± 2.05	c		
Supella longipalpa	INDIA-A	19.40 ± 3.78	a	27.41	<0.01
	INDIA-E	13.40 ± 4.56	ab		
	ZAPI	12.40 ± 2.97	b		
	CATCHMASTER	0.80 ± 0.45	c		

• Non-significant differences among trap catches for each species (Tukey post-hoc test) are marked with equal letters ($p<0.01$).

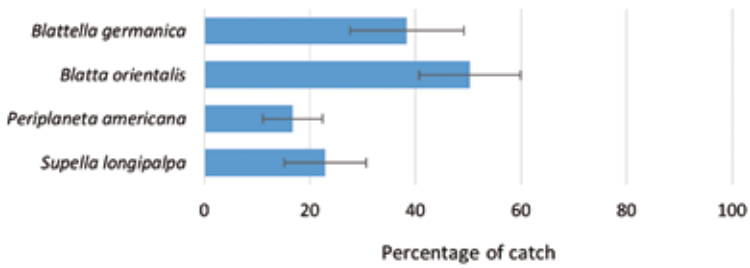

Figure 3 - Percentage of each species of cockroaches caught at the end of the experiment by all the traps. The value includes all species, all the life stages and both sexes. Bars represent Standard Error.

Table 2 - Analysis of captures of females, males and juvenis with ZAPI trap for each specie. Data were normalized and tested with Analysis of Variance (ANOVA) if normally distributed or else with Kruskal Wallis test followed by a Dunn test.

Species	Test applied	Typology	Mean ± sd	•	P-value
B. germanica	ANOVA	Females	38.00 ± 26.83		0.10
		Males	56.00 ± 16.73		
		Juvenis	27.33 ± 11.88		
S. longipalpa	ANOVA	Females	20.00 ± 7.07		0.12
		Males	36.00 ± 16.73		
		Juvenis	22.67 ± 9.83		
P. americana	Kruskal Wallis	Females	6.00 ± 5.48	a	0.01**
		Males	4.00 ± 5.48	a	
		Juvenis	18.00 ± 6.06	b	
B. orientalis	ANOVA	Females	42.00 ± 13.04		0.07
		Males	66.00 ± 19.49		
		Juvenis	62.00 ± 13.46		

•Non-significant differences among trap catches for each species (Tukey post-hoc test) are marked with equal letters ($p<0.01$). Codes meaning: '***'=$p<0.001$; '**'=$p<0.01$; '*'=$p<0.05$

observed.

Broken legs of each species were present on the glue surface of all traps. Also, footprints were found mostly on the glue surface of the ZAPI trap with *P. americana.*

The addition of the attractant tablet in the INDIA traps did not improve the catch, as shown by the Tuckey's test for post-hoc comparisons for each species in Table 1.

Finally, just the ZAPI trap showed for *P. americana* a selection in catch for juvenis (neanid and nymph) (Tab. 2).

Discussion

In this experiment, there was not a marked trap selectivity toward given species. The INDIA-A showed the best performance with each species.

The catch rate depended more on the species than on the trap; some species have a greater predisposition to be caught than others, irrespective of the trap.

Blatta orientalis was caught at the greatest rate (50.3% of the specimens tested). According to our observation, this species used the trap as a shelter. During the test, when the light was turned on to collect the traps, almost all the cockroaches were inside the shelter or inside the trap usually, rather than walking in the arena. This probably affected the percentage of catch. Another factor to consider is that *B. orientalis* tarsi are equipped with very small, non-functional *arolia* compared to those of the other three species (29). *Arolia* are adhesive structures that allow cockroaches to climb smooth surfaces. These structures, when well developed, can help cockroaches to hold to the outside of the glue surface when they are in the trap, facilitating the escape. *B. orientalis* cannot take advantage of its *arolia* because they are too small. This result is in line with other studies demonstrating that *B. orientalis* is the easiest species of the most common cockroaches to be caught with sticky traps (30, 31).

On the contrary, *P. americana* was the species caught at the lowest rate (16.8%). A reason for this could be its bigger size and strength that make it able to detach from

the glue.

Only 23% of the specimens of *S. longipalpa* were caught, just a little more compared to *P. americana*. In residential buildings, *S. longipalpa* is often found on vertical surfaces at eye level or above (32). Consequently, to improve the catch of this species, the traps could be placed in vertical position - for example, attached to the walls or on the lateral surfaces of furniture. Moreover, in domestic spaces, traps should also be positioned inside the furniture.

None of the traps caught all the specimens present in the arena. The hypothesis for this is that cockroaches are able to memorize the risk related to the trap (30, 33); the insects that managed to escape from the trap did not re-enter it. Many studies show that traps cannot replace the insecticide treatment (26, 30, 33-35) precisely because they never catch all the specimens even if there is still free space on the glue surface.

The effectiveness of a sticky trap is strongly influenced by its physical characteristics (24, 26, 30, 35). A seemingly important feature is the presence of entryways with a sloped ramp; studies showed that catch is enhanced by inclined ramps (24, 36). Moore *et al*. (30) found that a trap with a rectangular section (Raid Roach Trap®) was more efficient than a trapezoidal one (Holiday Roach Coach®), but the first had internally directed flaps at both openings that probably improved the catch. In our study, the INDIA and the ZAPI traps were equipped with two entryways with sloped ramps and their catch rate was considerably higher than the CATCHMASTER, which only had openings without ramps.

On the glue surface of all the traps, tarsi and tibiae of all species were found, particularly of *P. americana*. Furthermore, in the ZAPI traps also footprints were found, especially with *P. americana*. These observations suggest that the ZAPI trap's glue is less powerful than the INDIA one, and so, cockroaches are able to walk on it. The strength of the INDIA trap glue instead prevents cockroaches from escaping without tearing off a part of their leg. There were no footprints in the CATCHMASTER trap, but cockroaches were often found on the border of the glue surface. It is possible that they detached from the glue without exceeding the threshold of the trap.

The ability of detaching from the glue varied also according to the species. Moore *et al*. (30) found that *P. americana* and *B. orientalis* were particularly able to escape from sticky traps.

The presence of the attractant in the INDIA-A did not increase the catch in a significant way in respect to that of the INDIA-E. Smith *et al*. (24) also found that a trap provided with its attractant tablet only improved its catch by 5%. Although the CATCHMASTER contained an attractant inside the glue, its performance was the worst. Several studies showed that food lures, like peanut butter, distiller's grain and bread soaked in beer, have a higher attractant power than commercial lures (35, 37). According to this statement, best results could be obtained by traps herein tested by replacing their attractants with a more powerful lure.

Conclusions

In conclusion it is clear that the trap design, the type of glue and the aroma of the attractants used make that not all the traps are appropriate for all the species of cockroaches.

Within the tested traps our results indicate that the INDIA-A is the best trap to employ with each species we tested. *P. americana* and *S. longipalpa* were not adequately caught by any of the tested traps; therefore, the behavior of these species should be better investigated, to more successfully create traps modeled to catch them. When a monitoring of cockroaches is implemented, the right choice of the trap will deeply

affect the results. The risk of a bad choice is the underestimation of the population of these pests with important consequences on environmental hygiene.

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Riassunto

Valutazione dell'efficacia di tre trappole adesive nei confronti di quattro specie di scarafaggi (hexapoda: blattaria) mediante un test di uso simulato

Introduzione. Le blatte sono gli infestanti maggiormente oggetto dei programmi di disinfestazione del sistema sanitario in Italia. L'interesse igienico-sanitario è legato al ruolo di vettori meccanici di patogeni e al potenziale allergologico. Le trappole adesive sono lo strumento migliore per monitorare la presenza di questi insetti e sul mercato ne sono disponibili diversi modelli. Nella maggior parte dei casi le trappole non sono indicate per una specie ma genericamente per gli scarafaggi. Le blatte presenti negli ambienti urbani differiscono per morfologia, dimensioni e abitudini e di conseguenza, l'efficacia della trappola potrebbe cambiare in relazione alla specie bersaglio.

Materiali e metodi. In questo studio sono state messe a confronto tre delle trappole più utilizzate in Italia: la trappola INDIA con e senza la sua pastiglia attrattiva (di seguito denominata INDIA-A e INDIA-E, rispettivamente), la trappola ZAPI Simply e la trappola CATCHMASTER Spider & Insect Glue. Le quattro specie di blatta (Blattodea) oggetto di studio sono le più diffuse in Italia: *Blatta orientalis* (L.), *Periplaneta americana* (L.) (Blattidae), *Blattella germanica* (L.) e *Supella longipalpa* (F.) (Blattellidae). Ogni specie di scarafaggio è stata testata separatamente all'interno di arene contenenti una delle trappole. Ogni test (una determinata specie con un tipo di trappola) è stato replicato cinque volte.

Risultati e discussione. La trappola INDIA-A ha raccolto più scarafaggi di ogni specie, seguita dall'INDIA-E. La trappola ZAPI ha catturato meno esemplari di ogni specie rispetto alle trappole INDIA, con la sola eccezione di *B. orientalis*, per la quale la trappola ZAPI ha catturato più delle trappole INDIA-E. La trappola CATCHMASTER ha avuto prestazioni significativamente inferiori per tutte le specie. *B. orientalis* è stata la specie più abbondantemente catturata da tutte le trappole, seguita da *B. germanica*, *S. longipalpa* e *P. americana*. Nessuna differenza significativa è stata osservata nella cattura secondo lo stadio di sviluppo. In generale, non si è evidenziata una particolare predisposizione di alcuna trappola nel catturare una determinata specie.

Conclusioni. Non è possibile indicare un modello di trappola per ogni specie di blatta ma è chiaro come le trappole abbiano prestazioni differenti in termini di attrattività e cattura. La scelta della trappola influisce pertanto sui risultati del monitoraggio e, di conseguenza, sulla valutazione della popolazione infestante, con importanti conseguenze sulle misure da intraprendere per il loro controllo.

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