Article

Ecological investigation, density, infestation rate and control strategy of German cockroach, *Blattella germanica* (L.) in two hospitals in Ismailia, Egypt

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Abstract
A study was conducted to investigate the ecological situation, density, infestation rate and control strategy of German cockroach, *Blattella germanica* indoors in two hospitals in Ismailia Governorate, Egypt. The sticky traps method was used for 12 months in 2012. The cockroach index, sanitation and ventilation rate tables were tools to investigate the effectiveness of sanitation and related factors on *B. germanica* in Ismailia. Results showed that the population density of *B. germanica* increased gradually from January to July, and then decreased gradually till December of 2012 in both hospitals. The population density of *B. germanica* captured from hospital 1 (urban) was higher than hospital 2 (rural) in all months. Moreover, the number of German cockroach caught from different apartments in both hospitals was very significant different. Among these apartments, kitchen had the highest number of German cockroach, density, infestation rate and percent of nymphs. The highest population density was in kitchen (298.44), followed by dry food store (69.99), furniture room (25.91) and patient room (8.94), for hospital 1. However, the population was low in all apartments in hospital 2. Although several stages of *B. germanica* were caught from two hospitals, nymphs showed the higher infestation rate in all apartments surveyed in both hospitals. The infestation rate of nymphs was 92.5% in hospital 1 and 63.06% in hospital 2. In addition, temperature and humidity were measured in hospitals to study the relationship between population density of *B. germanica* and these parameters. There was a positive correlation between temperature and the population density for hospital 1 and for hospital 2. The correlation was negative between humidity and population density in both hospitals. In conclusion, integrated control measures should be taken according to the seasonal fluctuation, population density in hospitals in Ismailia. It should put the emphasis on environmental management plus physical control, chemical control and biological control. Sanitation, good ventilation has positive impact in reduction of German cockroach infestation.

Keywords German cockroach; hospitals; density; infestation rate; temperature; humidity.

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1 Introduction

German cockroach (*Blattella germanica* L.), belonging to the Order Dictyoptera, Family Blattellidae, is the most important worldwide pest species due to small size, nutritional habits and specific behavior (Foltz, 2001) in addition to compliance with the human environment can cause transmission of pathogen factors and also cause aggravate allergic diseases, asthma and even invasion to human (Berenji et al., 2007; Salehzadeh et al., 2007).

Today, German cockroach is the important pest of residential, commercial, office and industrial places and is shared with humans in food, water, shelter and warmth. German cockroach eats any human, animal and plant foods or drinks, human and animal materials, leather, glue, hair, wall paper, fiber and stiffness in binding to books and regurgitates parts of eaten foods which can cause distribution of infection and food spoiling, wasting.

Also, secretes nauseating discharges from oral or body glands that cause cockroach specific smell remains for a long time on the food or in its environment. Fear due to existence of cockroaches and its horrified appearance are the most important factors which are considered as an introduced pest. Cost of fighting to this pest insect is allocated significantly own income of families. German cockroach can be shelter of bacteria (Zarchi and Vatani, 2009) and intermediate host of pathogenic intestinal worms (Berenji et al., 2007) also can transfer viruses, fungi and protozoa that they pass to adverse effects on human and other vertebrate animals.

In recent years, a number of studies have been carried out to determine the population dynamic of cockroaches in some hospitals and apartments in Turkey (Kutrup, 2003) and Korea (Kwon and Chon, 1991; Dong, 1995). In these studies, it was found that among cockroaches caught in hospitals, *B. germanica* was the predominant species (Kwon and Chon 1991; Dong 1995). It was also claimed that the population density of this species correlated with pest control programmes used in hospitals (Dong, 1995). On the other hand, the insecticides used against *B. germanica* have negatively affected the population dynamic of this species in Turkey (Kutrup, 2003). However, these studies do not provide further information about the population dynamics of cockroaches in hospitals and the influence of temperature and humidity.

German cockroach incidence and abundance has been estimated by various methods, for example trapping, night visual counting and flushing by insecticides (Gemeno et al., 2011). Nevertheless, sticky traps have become the most commonly used monitoring method. Commercial sticky traps for crawling insects are generally recommended as cockroach traps, i.e. convenient for monitoring of any cockroach species.

The literature review reveals that information about the population dynamic of German cockroach in hospitals in Egypt, such as Ismailia region is rather scarce, and no comprehensive study has been undertaken. Therefore, the present study was performed to evaluate the effectiveness of sticky traps as a tool for IPM control approach on all life stages (adult, nymph, and ootheca) of German cockroach in two hospitals, one in rural and the other in urban area in Ismailia Governorate, Egypt. Moreover, how the sticky traps reveal the presence, population density and infestation rate of German cockroach in all apartments of the two hospitals. And the influence of some parameters such as humidity and temperature on the population dynamics, infestation rate of German cockroaches in previous hospitals in Ismailia.

2 Materials and Methods

2.1 Sticky trap

Cockroach glue trap house is a sticky trap, which does not use any insecticides but uses a simple device that folds into a trapezoid paper house (10x20x2 cm^3). The sticky area for catching cockroaches is about 9.5x19.5 cm^2. There are four entrances that cockroaches can use. Cockroaches were lured into the trap by built in attractants and attached baits that were placed in the middle of the sticky area.

2.2 Survey and selection of hospitals

The study was conducted in two hospitals, one in urban area (H 1) and the other in rural area (H 2), in Ismailia Governorate, Egypt. Experiment carried out in four apartments of each hospital (kitchen, patient room, dry food store, and furniture store). The size of apartments were 100 m^2, 40 m^2, 10 m^2 and 40 m^2 for kitchen, dry food store, furniture store and patient room, respectively in (H 1), where, it was 400 m^2, 20 m^2, 15 m^2 and 15 m^2 for (H 2). These apartments were surveyed using glue board traps. Three glue board traps were placed in the kitchen, patient room, dry food store, and furniture store of each hospital. Standard trapping locations were in apartments under and above the kitchen sink, beside the stove, beside the refrigerator and beside the shelf or water heater in the patient room. The traps were placed such that one edge was touching a wall or a vertical component of the apartment. The numbers of trapped German cockroach were counted monthly (during three days) from January to December of 2012.

2.3 Ecological parameters

The humidity and temperature in the sampled sites of hospitals were measured by a hygrothermometer. In order to estimate the population dynamic of German cockroaches, the mean values of humidity and temperature records were compared with the population density of German cockroach.

2.4 Statistical analysis

Data obtained were statistically analyzed through ANOVA (SAS Institute, 2002). When F-test was significant, means were separated using Tukey's Honestly Significant Difference (HSD) Test at the 0.05 level of significance.

$$\text{Correlation coefficient (r)} = \frac{1}{n-1}\sum(X - \mu x)(Y - \mu y) / \sigma_x \sigma_y$$

where μx and μy represents the mean of the data set *X* and *Y* respectively. The σ_x and σ_y represents the standard deviation of the data set X and Y respectively.

German cockroach density = no. of counted cockroaches/no. of traps × no. of days.

Table 1 Cockroach index.

Number of captured cockroaches/ Trap/ unit/ month	Cockroach Index
0-1	Clean
1-3	Low
3-8	Moderate
8-26	High
26-50	Very high
≤ 50	Abundant

Table 2 Scales used to rate the degree of sanitation (modified from Wang and Bennett 2006).

Rating	General Condition	Amount of clutter dinner area	Amount of trash on floor	Amount of food on floor
1 to 6	Clean = 1-2 Pretty clean = 3 Dirty = 4-5 Severely dirty = 6	Few = 1 Many = 2	None = 0 Some = 1 Many = 2	None = 0 Some = 1 Many = 2
Description		Many= more than one observable clutter	Some= just observable after looking for Many= visible without any searching	Some= visible after exact investigation Many= can see them several points obviously

Table 3 Ventilation index.

Rating	General condition	Description
1-4	One window/10 m^2= 1 One window/50m^2= 2 One window/100m^2= 3 Area without window= 4	Good ventilation Fairly ventilation Bad ventilation Very bad ventilation

3 Results and Discussion

Data obtained from Fig. 1 showed that the population density of German cockroach, *B. germanica* increased gradually from January to July, while it was decreased gradually from August to December of 2012 in both hospitals. Moreover, Fig. 1 revealed that population density of *B. germanica* captured from hospital 1 (urban) was higher than hospital 2 (rural) in all months of 2012.

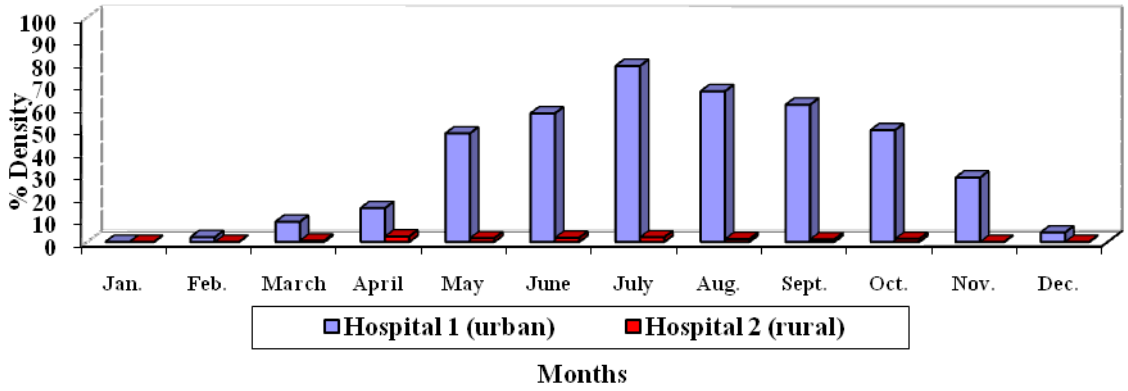

Fig. 1 the density of German cockroach, *Blattella germanica* captured from hospitals 1 and 2 during 12 months of 2012.

Fig. 2 showed the infestation rate of German cockroach, *B. germanica* caught from the two hospitals. The nymphal stage showed higher infestation rate in all apartments surveyed in both hospitals. The infestation rate of nymphs was 92.5% in hospital 1 and it was 63.06% in hospital 2. The infestation rate of males and females in both hospitals was almost equal. It was 2.96%, 3.49% for hospital 1 and 17.11%, 18.01% for hospital 2.

The population density caught from four apartments in both hospitals showed in Fig. 3. It was seen that the highest population density was in kitchen (298.44), followed by dry food store (69.99), furniture room (25.91) and patient room (8.94), for hospital 1. The population density caught from hospital 2 was low in all different apartments. It was 3.26, 3.94, 0.22 and 3.84 for kitchen, patient room, dry food store and furniture store, respectively.

The population densities, individual/ 10m^2, infestation rate, percent of nympal stage, males, females, females with ootheca and percent of females to males of *B. germanica* caught from four apartments in two hospitals are given in Tables 4 and 5. Data revealed that the number of German cockroach caught from different apartment in both hospitals was very significant differences. Among these apartments, kitchen had the highest number of German cockroach, number of individual/ 10m^2, infestation rate and percent of nymphs.

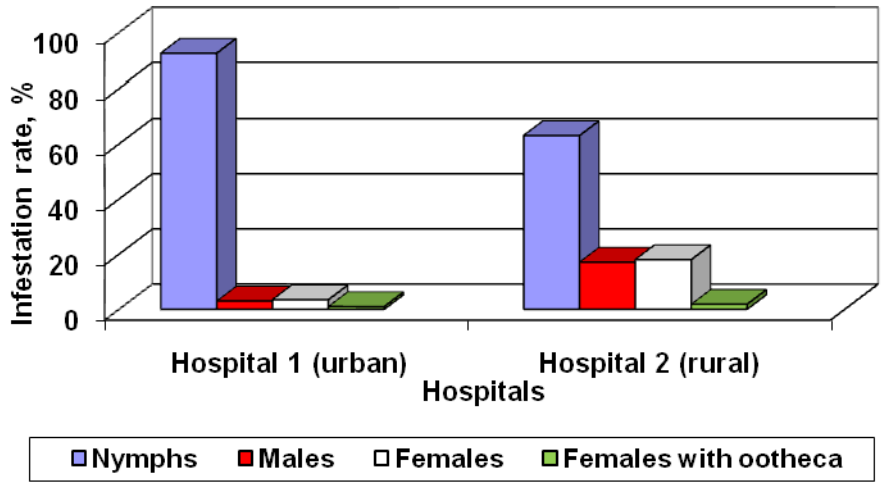

Fig. 2 The infestation rate of German cockroach, *Blattella germanica* captured from hospitals 1 and 2.

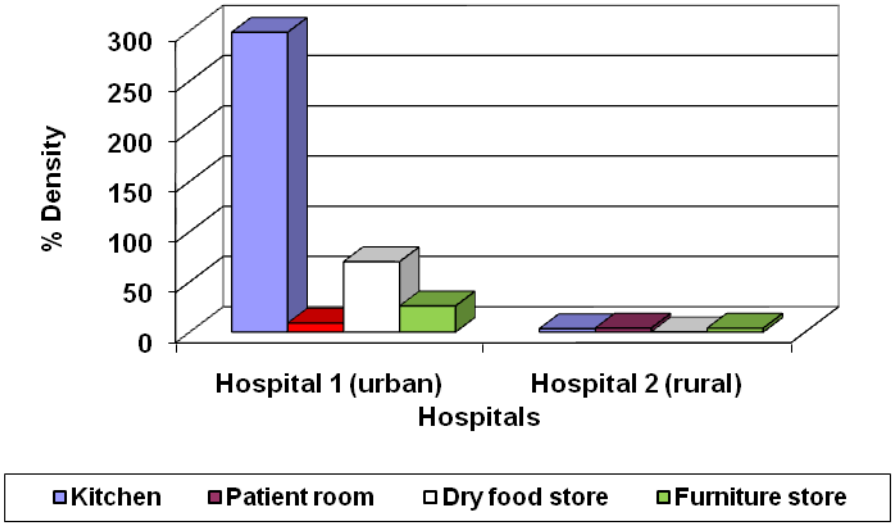

Fig. 3 The density of German cockroach, *Blattella germanica* in the four apartments of hospitals 1 and 2.

Although several stages of *B. germanica* were seen, the nymphs showed higher number and infestation rate in all four apartments in both hospitals. It was observed that the low percent of *B. germanica* was females carrying ootheca in both hospitals. Also, data revealed that hospitals 1 was more infestation with all stages of *B. germanica* than hospital 2.

Table 4 Population density and infestation rate of German cockroach, *Blattella germanica* in the four apartments of hospital 1.

Places	n	Individual/ $10m^2$	Nymphs %	Males %	Females %	Females with ootheca %	F/M	Infestation rate %
kitchen	2686 a	268.6	91.47	2.08	2.27	0.52	1.34/1	71.07
Patient room	230 c	57.50	82.60	7.39	7.82	2.17	1.35/1	6.08
dry food store	630 b	157.5	88.73	3.96	5.39	1.74	1.80/1	16.67
Furniture store	233 c	233	84.12	6.00	7.29	3.00	1.71/1	6.16
Total	3779	-	-	-	-	-		100

n= number of German cockroach

Means followed by the same letter in a column are not statistically different by Tukey's HSD (P=0.05)

Table 5 Population density and infestation rate of German cockroach, *Blattella germanica* in the four apartments of hospital 2.

Places	n	Individual /10m^2	Nymphs %	Males %	Females %	Females with ootheca %	F/M	Infestation rate %
kitchen	30 b	0.75	63.33	20.0	16.66	0.0	0.83/1	26.78
Patient room	36 b	18	63.88	16.66	19.44	0.0	1.16/1	32.14
dry food store	2 c	1.33	1.0	1.0	0.0	0.0	0.0/1	1.78
Furniture store	44 a	29.33	63.63	13.63	18.18	4.45	1.33/1	39.28
Total	112	-	-	-	-	-	-	100

n= number of German cockroach

Means followed by the same letter in a column are not statistically different by Tukey's HSD (P=0.05)

Tables 6 and 7 revealed that the mean relative humidity measured at different apartments in the hospitals was similar to each other, while the mean temperature had very different value during months of 2012. There was a positive correlation between temperature and the population density of German cockroach, *B. germanica* (R= 0.94, P≤ 0.01) for hospital 1 and (R= 0.67, P≤ 0.01) for hospital 2. Vice versa, the correlation was negative between humidity and population density in both hospitals. It was -0.67 and -0.61.

Table 6 Correlation between temperature, humidity and density of German cockroach, *Blattella germanica* in hospital 1.

Months	Mean Temperature °C	Density	Mean Relative Humidity (R.H)	Density
Jan.	15	0.0	73	0.0
Feb.	19.6	2.1	64.5	2.1
March	19.8	8.89	67.5	8.89
April	23.9	15.03	52.75	15.03
May	28.07	48.35	55.25	48.35
June	29.5	57.27	60	57.27
July	30.3	78.4	53.3	78.4
Aug.	31.7	67.1	57.3	67.1
Sept.	30.1	61.1	63.5	61.1
Oct.	27.7	49.79	58.28	49.79
Nov.	23.1	28.7	63.5	28.7
Dec.	17.9	4.2	69.7	4.2
Correlation coefficient (R*)		0.94	(R)	-0.67
$X_{Mean}(\mu_x)$		34.24		34.24
$Y_{Mean}(\mu_y)$		24.72		61.54
σ_x		27.81		27.81
σ_y		5.61		6.50

*Significant correlation at the 99% level.

Traps are very useful tools for detecting cockroaches and many other crawling insects in the environment. The following animals were found in the monitoring traps placed in apartments: mice, ants, small flies, spiders, and beetles. Traps offer the best way to monitor German cockroach populations. By placing traps in several locations and inspecting them regularly, we can identify the areas of most severe infestation and know where to concentrate control efforts. Traps are also helpful for guiding pesticide applications thereby reducing pesticide use. In addition, sticky traps are useful for evaluating insecticide efficacy against cockroaches (Shahraki et al., 2010). Traps are convenient to use, non-toxic, and inexpensive. Hence, they are frequently

used in cockroach management programs.

Table 7 Correlation between temperature, humidity and density of German cockroach, *Blattella germanica* in hospital 2.

Months	Mean Temperature °C	Density	Mean Relative Humidity (R.H)	Density
Jan.	14.75	0.0	71	0.0
Feb.	16.75	0.0	59.25	0.0
March	16.9	0.55	66	0.55
April	22.3	2.44	53.5	2.44
May	26.3	1.65	60	1.65
June	28.2	1.86	66	1.86
July	30	2.07	60.5	2.07
Aug.	31.5	1.25	60.1	1.25
Sept.	29.9	1.1	62	1.1
Oct.	28.4	1.33	56.25	1.33
Nov.	23.6	0.0	63.25	0.0
Dec.	16.7	0.0	71	0.0
Correlation coefficient (R*)		0.67	(R)	-0.61
$X_{Mean}(\mu_x)$		1.02		1.02
$Y_{Mean}(\mu_y)$		23.77		62.40
σ_x		0.89		0.89
σ_y		6.13		5.36

*Significant correlation at the 99% level.

German cockroach numbers caught in traps do not change significantly over time at most trap locations (Nalyanya and Schal, 2001). This feature is useful for estimating population distributions and population changes after pesticide applications. Field studies in apartment buildings showed very consistent distribution patterns. Areas around refrigerators and stoves in the kitchens accounted for 60% of the trap catches (Tawatsin, 2001). Traps can remove a large number of cockroaches when they are placed in multiple locations. Despite the large number of cockroaches that can be removed by traps, traps are not recommended as the sole method for eliminating cockroaches because they are not effective in significantly reducing the cockroach population levels in the living environment (Wang and Bennett, 2006).

Previous studies revealed that German cockroach, *B. germanica* successfully breeds in the kitchens of hospitals, apartments, tea rooms, hotels, private houses and restaurants. Specimens belonging to this cockroach could easily visit other places to find food (Kutrup, 2003; Agrawal and Tilak, 2006). These results were similar to ours.

Although hospitals and apartments in this study were not sufficient in number to allow a definite conclusion about the feeding and breeding of German cockroaches, it was found that kitchen of hospital (1) was suitable for German cockroach because of their suitable temperature and humidity (Fig. 3). Moreover, both of bad ventilation and sanitation in hospital (1) due to increased the density and infestation rate of *B. germanica*. In addition, dry food store in hospital (1) was suitable as well as kitchen for *B. germanica* (Table 4).

The greatest number of *B. germanica* caught from kitchen and dry food store was nymphal stage, while females carrying ootheca were very low in population density and infestation rate in kitchen and dry food store. It was also observed that nymphs mostly preferred to remain in areas such as kitchens, where food and water were adequate. An alternative explanation of the high occurrence of nymphs in the kitchen would be an

migration of nymph during the feeding period to the kitchens due to adequate humidity, temperature, sanitation and ventilation, which might have been an important factor for nymphs in the period of development.

Many researches indicated that, with the increase of humidity, increase the population and infestation rate of cockroaches (Kutrup, 2003; Agrawal and Tilak, 2006). However, unlike these results, we observed that the density and infestation rate were very low at the maximum average of humidity in the winter months (January and December), where low temperature and low activity of German cockroach.

4 Conclusion

B. germanica successfully breeds in hospitals because of high humidity, high temperature and presence of food. It is essential that further studies be carried out in order to find better control methods for this cockroach in hospitals. Since *B. germanica* still has a high population density in hospitals despite the large amount of insecticide are used, we believe it is necessary to continue work on this matter, in order to obtain a more comprehensive solution for this problem.

Integrated control measures should be taken according to the seasonal fluctuation of cockroach density in Ismailia. It should put the emphasis on environmental management plus physical control, chemical control and biological control. It should strengthen the control of German cockroach in hospitals via increase public awareness of disease prevention, interest with good ventilation and sanitation, at the same time strengthen the surveillance of density, population dynamics and resistance, and work out timely the control measure according to monitoring data.

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