THE IMPACT OF A SINGLE TREATMENT WITH THE CHITIN SYNTHESIS INHIBITOR LUFENURON ON GERMAN COCKROACH *BLATTELLA GERMANICA* (L.) (DICTYOPTERA: BLATTELLIDAE) POPULATIONS

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Abstract - The present investigation demonstrates the effect of a single treatment with a chitin synthesis inhibitor (lufenuron) on small, medium and large nymphs as well as adults of the German cockroach, *Blattella germanica* (L.). The trial was conducted as a long-term field study in three mass food producing kitchens. The spraying was carried out by the use of a compressed-air sprayer at a rate of approximately 1 litre/200 mg a.i./25 m in a 0.3-0.5 m band. The changes in population size, age structure, etc. were monitored with sticky traps. Within the first 4 to 6 weeks after the treatment, the cockroach populations were reduced by more than 95% in two localities. Approximately 4 months after the treatment, the number of adults began to rise again in one of the localities. The age structure was followed in all three localities treated. It was done by calculating the nymph-to-adult ratio and relating it to the similar value obtained before the treatment. In one locality the population was so heavily affected by the treatment that the age structure could only be followed for a short period, and in one of the other two localities immigration from an adjacent building affected the results. In the last locality, the age structure could be followed in detail throughout the trial period. In the first 4 to 6 weeks after the treatment the nymph-to-adult ratio decreased to 0.15 compared to a value of 0.63 before the treatment. After this initial period it increased to 0.96. This indicates that the initial high proportion of adults in the population was followed by a high proportion of nymphs. Then for a couple of months the nymph-to-adult ratio could not be calculated, due to the low number of specimens, but when it was possible to calculate the nymph-to-adult ratio again, it was still high indicating an over-representation of nymphs. Four months after the treatment, the nymph-to-adult ratio declined rapidly indicating a synchronized moult into adults. It is shown that adult cockroaches living in mass food producing kitchens in Denmark only live for 30 to 40 days. This is quite a short time compared to similar data obtained in laboratories. The consequences of such a short lifetime are that a female only has the possibility to produce one ootheca in her lifetime. It is also demonstrated that nymphs need 2½ months to develop into adults in such a domestic environment.
Keywords - Lifetime, sticky traps, population size, age structure

INTRODUCTION

Chitin synthesis inhibitors based on benzoylphenyl ureas have been evaluated for control of a number of different insect pests in forestry, agriculture, household and urban areas (Wright and Retnakaran, 1987, DeMark and Bennett 1989, Ross and Cochran 1990, Mosson *et al.* 1995). The effect of different chitin synthesis inhibitor against cockroaches has been described by Weaver *et al.* 1984 and Koehler and Patterson 1989. The nymphal stages are - when exposed to sufficient doses of chitin synthesis inhibitor - not capable of moulting normally, and they will die in the process. This means that the effect will be a reduction in the number of nymphs and consequently a reduction in the number of adults when the old adults die out and no new ones are produced to replace them.

The goal of the present investigation was to study the changes in the ratio between nymphs and adults of the German cockroach, *Blattella germanica* (L.), after a single treatment with a chitin synthesis inhibitor (lufenuron, Novartis), and thereby investigate the development of free living cockroach populations. The trial was a long-term trial in three mass food producing hospital kitchens. A German cockroach population in a non-treated locality was monitored over a short period of time to indicate the natural fluctuations and age structure in a *B. germanica* population that had not been subjected to any control measures.

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MATERIALS AND METHODS

Residual treatment was carried out with a compressed-air sprayer (Gloria, prima 5, Drucksprüngerät) at a rate of approximately 1 litre/25 m in a 0.3-0.5 m band of spray or just short of run-off using 200 mg a.i/l. Application was made at the top and bottom of the walls, in areas around pipes and lamps, as well as behind fixtures such as electric cookers, ovens and cupboards. When possible the stainless steel equipment was dismantled and treated on the interior parts.

The change in size of the cockroach population and the change in age structure during the trial were estimated by means of sticky traps positioned in the vicinity of cockroach harbourage areas. (Superstrong Cockroach Sticky traps, China Pest Control Company Ltd., Taiwan). Ten traps were positioned in each kitchen, but due to cleaning and the general work-procedures it was expected that at least some of the traps would be ruined before they were collected. The number of small nymphs (nymph 1 was < 5 mm), medium nymphs (nymph 2 was 5 to 8 mm) and large nymphs (nymph 3 was > 8 mm) was recorded as well as the number of females and males. More than 100 small nymphs per trap were recorded as >100.

The sticky traps were in position between 3 and 5 days per week. For comparison the mean catch per traps and day was calculated. For the calculation of the nymph-to-adult ratio the accumulated catch of nymphs and adults was used. To evaluate the change caused by the treatment, ratios from before the treatment were compared with ratios for each week after the treatment. Therefore points below the x-axis in Figure 2 indicate that the fraction of adults is higher than before the treatment, whereas points above the x-axis indicate that the fraction of nymphs is higher than before the treatment. The small nymph counts were heavily affected by the fact that females caught on the trap would drop their oothecae, and all the newly hatched nymphs would be caught as well. Therefore only medium and large nymphs counts were used in the calculation of the nymph-to-adult ratios obtained by the treatment. Furthermore counts of less than 10 nymphs or adults were not analysed to avoid the impact on the nymph-to-adult ratio by very small samples.

The three hospital kitchens as well as the untreated locality at a zoological garden were all situated in Copenhagen. In all localities the staff was well aware of the trial and did their utmost not to disturb the traps, although they were asked not to change their normal cleaning procedures, etc. None of the localities had been treated with insecticide for six months when the trials were initiated. Before that period deltamethrin had been used in all the kitchens.

The buildings housing the kitchens had been built in the beginning of the century, but the kitchen areas have been renovated several times since then. Lately also cockroach problems had been taken into consideration when alterations had been made, e.g. no fixtures placed directly against the wall, repair of damage to plaster, etc. Nevertheless, the kitchens were old, and there were still some cracks around pipes and around the base of stoves and ovens, etc. These cracks gave the cockroaches access to ideal hideouts inside stainless steel equipment and around steam pipes mounted in deep cut, steel plate covered, hollows in the brick wall.

The kitchens were cleaned daily with disinfectants and washed down with hot water, but due to the general layout of the buildings it was very clear that some areas were only cleaned properly at the spring cleaning. There was some difference in the size of the kitchens: no. 1 produced 450 meals/day, no. 2 produced 80 meals/day, and number 3 produced 300 meals/day.

The reference locality was used to illustrate how a cockroach population would develop if no control measures were taken. The condition at this locality was nearly ideal for cockroaches, with high temperature and high humidity and with food scattered around. Only two traps could be used throughout the period as the others were either covered by *P. americana* after a short while or ruined by an armadillo. Cleaning or any other activity which could seriously affect the catch never took place.

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RESULTS AND DISCUSSION

In order to evaluate the size of the populations in each locality before treatment, the direct average and standard deviation of the counts per sticky trap per day were calculated and presented in Table 1. In contrast to the others the results from locality no. 4 were based on data from the whole period in which this locality was used.

The results could indicate that with respect to the three groups - nymphs, adults and the total number of cockroaches - the four localities were separated into two different groups. The two test localities no. 2 and no. 3 seemed to be equally infested and less heavily infested than locality no. 1 and locality no. 4. This is in accordance with the general impression when the localities were visited.

To evaluate the composition of the population with respect to nymphs and adults, the nymph (nymph 2 + nymph 3) to adult ratio was calculated and the average and standard deviation for the four localities are presented in Table 2.

Table 1. The average and standard deviation obtained by direct averaging of the pre-treatment counts on sticky traps per day.

Locality	n	Nymph	Adults	Adults + Nymph
1	24	11.6 ± 10.0	7.8 ± 6.7	19.4 ± 15.8
2	29	5.9 ± 9.2	1.4 ± 2.2	7.1 ± 11.1
3	40	2.9 ± 5.8	1.7 ± 3.1	4.6 ± 8.3
4	36	13.3 ± 9.1	4.1 ± 2.5	17.4 ± 10.5

Table 2. The average and standard deviation of the nymphs to adult ratio before treatment.

Locality	n	Average + Std. Dev. nymph-to-adult ratio
1	14	0.63 ± 0.28
2	6	1.54 ± 0.34
3	7	0.83 ± 0.61
4	9	0.69 ± 0.34

Based on the results presented above, it can be assumed that out of the three localities, locality no. 1 was the one resembling the reference locality (no. 4) the most, both in population size and age structure. Locality no. 3 was similar to no. 1 and no. 4 in age structure, but not so heavily infested as the other two. Locality no. 2 was not heavily infested compared with the untreated locality and the nymph-to-adult ratio of the population was high.

The impact of the treatment with chitin synthesis inhibitor was evident in all three localities (Figure 1), but the development was quite different. In locality no. 1 and no. 2 there was a more than 95% control of all age stages including adults after 37 and 27 days, respectively. In locality no. 2 the effect continues with small fluctuations for the rest of the trial period, whereas in locality no. 1 there was a new build-up of the population four months after the treatment. It was necessary to treat this locality with a conventional insecticide 160 days after the treatment with the chitin synthesis inhibitor. Locality no. 3 was in many aspects different; complete control was never obtained although it was clear that the population was affected (Figure 1). The reason for this can most likely be ascribed to a continuous reinfestation.

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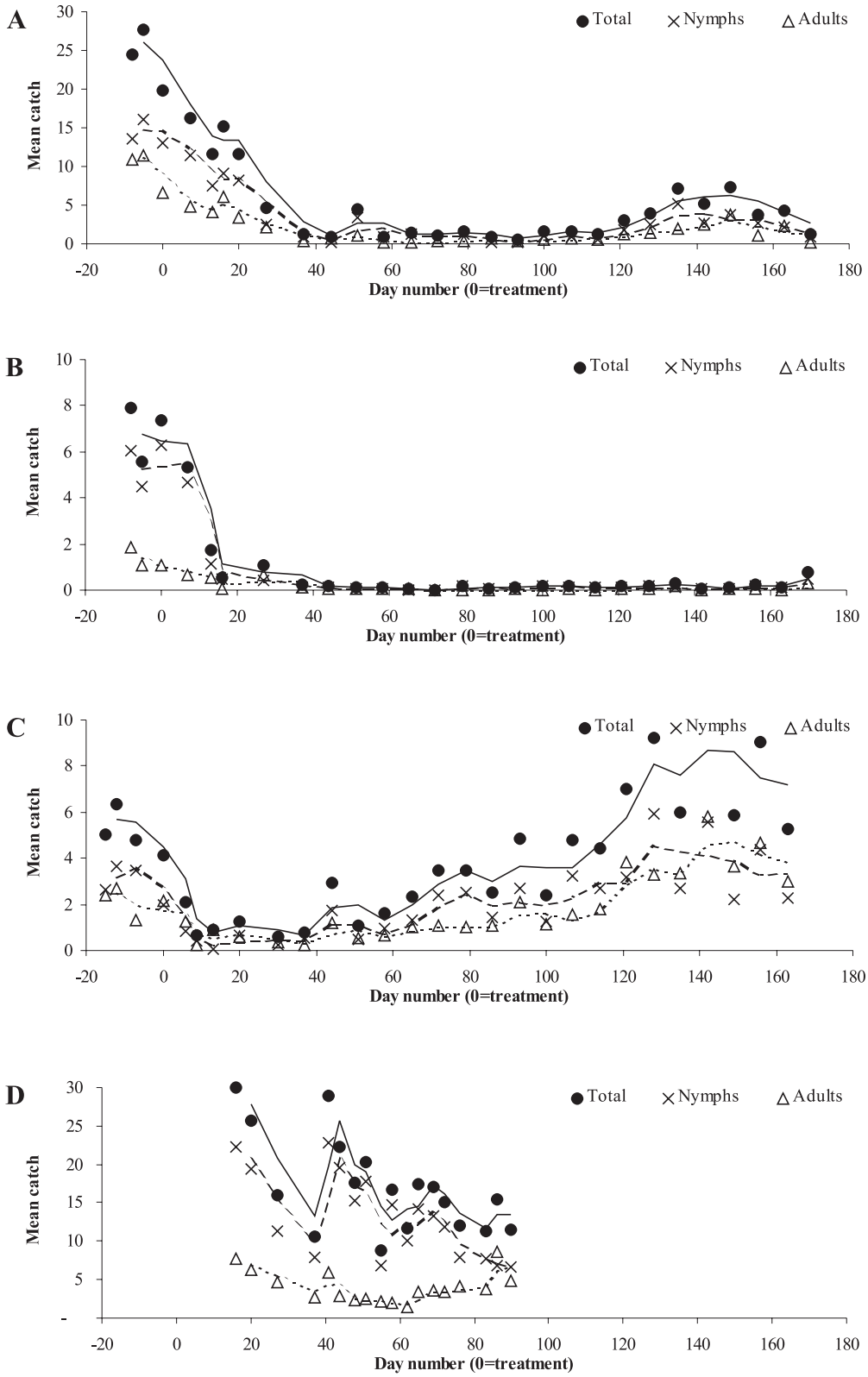

Figure 1. The mean number of nymphs and adults, as well as the total number caught in the sticky traps. The curves given represent the running mean of two consecutive numbers.
A= Locality no. 1, B= Locality no. 2, C= Locality no. 3 and D= Locality no. 4 (the control locality).

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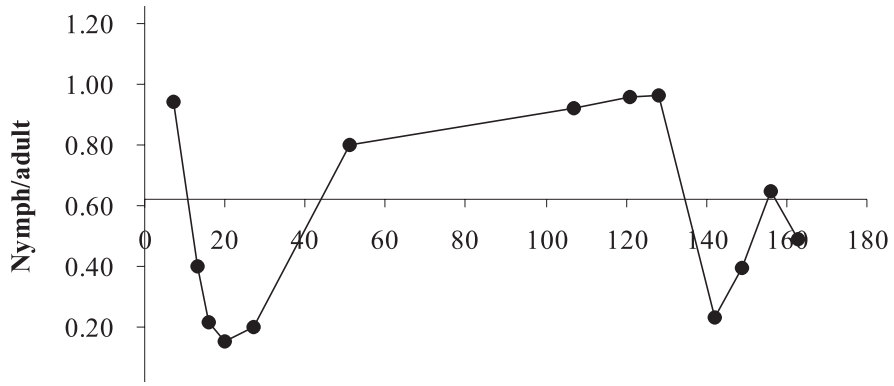

Figure 2. Locality no. 1. The development in the nymph-to-adult ratio. 0.63 marks the nymph-to-adult ratio before the treatment.

The approximately one-month-effective period of the treatment makes it possible for nymphs to be produced after the initial highly effective period. They might be produced by females which were young on the day of treatment or even from late-instar nymphs as such nymphs exposed to other benzoylphenyl ureas have been shown to reproduce normally if they survive to adults (DeMark and Bennett 1989, Ross and Cochran, 1990).

Neither locality no. 2 nor locality no. 3 facilitates a more detailed discussion of the nymph-to-adult ratio as the break-down of the populations happens so swiftly that the accumulated catch drops below 10 medium to large nymphs or adults within a fortnight. On the contrary, in the heavily infested locality no. 1, the age structure could be followed in detail. In the first 4 to 6 weeks after the treatment the nymph-to-adult ratio went down to 0.15 compared to a value of 0.63 before the treatment and then rose to 0.96. This indicates a high fraction of adults followed by a change to a high fraction of nymphs. Then for a couple of months the nymph-to-adult ratio could not be calculated due to the low number of specimens, but after approximately 120 days the population started to regain its momentum, at first with more nymphs than adults compared with the period before the treatment, but later (142 days after treatment) there were more adults than nymphs compared to the period before the treatment. After 160 days, the locality was treated with a conventional insecticide.

CONCLUSION

A chitin synthesis inhibitor like lufenuron would be expected to affect the composition (nymph and adults) as well as the size of the population. Within the first period of 30-40 days the nymph population was heavily affected and nearly reduced to zero. In locality no 1 it was possible to follow how the adult part of the population was developing when nearly no new adults were produced. Lufenuron affects the nymphs when they are moulting from one stage to the next (Kaakeh *et al.*, 1997, Schenker and Moyses, 1994). Death among the adults on the other hand must be assumed to represent normal causes in an environment like the ones used (Schenker and Moyses, 1994. It was demonstrated (Figure 1 and 2) that the numbers of adults decreased to a very low level as the old ones died out. This shows that adult cockroaches do not live more than 30 to 40 days in localities like the kitchens used in this investigation This is quite a short time compared to cockroaches living in laboratories (Cornwell 1968). Based on this it can be concluded that a female German cockroach would normally only be able to produce one single ootheca. Although she would have the capacity to produce a lot more (Cornwell 1968), she will not live long enough to do so. This decline in the populations in all three localities is very fast compared to similar results obtained under simulated domestic environment, where the decline sets in after

three to four months (Mosson *et al.* 1995), and where eradication is obtained after 12 month. Eradication was not obtained in more than one locality in the present investigation.

After a period of 2 1/2 months following a single treatment with lufenuron, the number of nymphs was rising again, whereas the number of adults was still very low and nearly constant at least at the beginning of the period. After four months these nymphs moult to adults illustrated by a change in the age structure towards a high fraction of adults. Then the synchronization caused by the treatment was dissolved and the population returns to a normal nymph-to-adult ratio and a normal development of the population.

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