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NYMPH-TO-ADULT RATIO IN GERMAN COCKROACH (DICTYOPTERA: BLATTELLIDAE) POPULATIONS AFTER TREATMENT WITH IMIDACLOPRID

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Abstract Control of adult roaches is usually not problematic as those life cycle stages are actively exploring the habitat for food sources. Nymphs are less mobile and therefore less likely to access a bait spot directly. Natural occurring populations of German cockroach (*Blattella germanica* L.) show a relatively constant ratio of nymphs in the total population of 0.6, which is largely unaffected by the size of the population and interference with conventional cockroach baits. Imidacloprid cockroach gel contains a proprietary capsule technology for encapsulating specific feeding stimulants. A detailed analysis of field trial data sets led to the discovery of unique modifications of the nymph ratio in populations treated with the new bait. A reduction of the standard nymph-to-total ratio 0.6 to 0.14 indicated an improved killing of larvae. The preferential elimination of larval stages is caused by the inclusion of the capsules containing a specific blend of feeding stimulants. A predicted consequence of this modulation is a long term inability for populations to recover.

Key Words *Blattella germanica*, gel bait, age structure, population dynamics, nymphs

INTRODUCTION

Control or management of the German cockroach *B. germanica* is widely achieved using insecticidal bait formulations, either by administration of gel spots or placement of bait stations. Insecticidal bait formulations feature several advantages over residual sprays that have made them commercially very successful in the last decade. Application is fast and convenient, requiring no specialized equipment and little cooperation of the homeowner. Good modern bait gels usually suppress cockroach population within several days and up to approximately 3 months. After this period, cockroach problems may return. This re-infestation has been attributed mostly to two factors: firstly, surviving individuals that start to reproduce in the absence of efficacious bait spots, and secondly, re-entry of new cockroaches from neighbouring sites (Runstrom and Bennett, 1990). Whereas re-invasion can only be addressed by treatment of the complete structure – an undertaking that is usually not accomplished due to restricted access to all flats – the elimination of the complete populations has been addressed by constantly improving the bait matrices. Cockroach bait gels have been optimized for palatability, and the horizontal transfer of active ingredients throughout the population (secondary kill) has been studied in detail (Silverman et al. 1991; Kopanic et al., 1999).

Detailed insight into age structure of field populations have been conducted in the past. Most data was collected while evaluating trap designs and suitable trap locations (Ballard and Gold, 1983; Ross et al., 1984). Those studies indicate that there is a relatively constant proportion of 60 to 70% of nymphs in an existing German cockroach population when using glue traps although this ratio may be different when using non-standard sampling methods (Owens and Bennett, 1983). This proportion is sometimes expressed as nymph-to-adult ratio (NAR) or more often as nymph-to-total ratio (NTR). Optimal suppression of the nymph population is thought to be a key success factor in managing cockroach infestation.

In this paper, we have evaluated a novel bait formulation concept of Imidacloprid cockroach gel, containing a proprietary capsule technology for encapsulating specific feeding stimulants, in terms of general population reduction, and moreover, in terms of analysis of the age structure in the surviving individuals.

MATERIAL AND METHODS

Insects

A laboratory strain of *B. germanica*, maintained for more than 15 years at the laboratories of Bayer Environmental Science, Monheim, Germany was used for the simulated use trials. This strain is susceptible to all classes of insecticides. The cockroach population in the field trial (Biarritz, France) has not been described as displaying any insecticidal resistance or aberrant feeding behaviour.

Baits

The experimental gel of 2.15% imidacloprid containing 5% capsules with additional feeding stimulants was compared with the conventional Maxforce[1] White IC (2.15% imidacloprid) in the laboratory part. In the field trial, a Maxforce gel containing 2.15% hydramethylnon was tested in addition.

Experimental Setup

Simulated-use trial. Full size rooms, measuring 3 x 5 meters were divided by a barrier into two smaller compartments measuring 3 x 2.5 meters. These compartments were equipped with 2 stacks of wooden planks separated by egg cartons as harbourages. A feeding source supplying dog food and water was present, and regularly replenished. Rooms were illuminated between 0600 and 1800. Temperature was 24 - 26°C. Relative humidity was not controlled. Six compartments received an initial population each of 50 male, 50 female and 100 third instar cockroaches. Compartments were left to become populated for 10 weeks before the gel baits were introduced. Visible, dead cockroaches were removed at the day of treatment. Three compartments were used as replicates for each of the two treatments. In each compartment, 4 spots of 200 mg bait gel were placed in the corners. Dead cockroaches were counted and removed at regular intervals.

Field trial. A suitable multi-unit housing block was selected in the city of Biarritz, France. 36 apartments were identified for participation in the trial. All 36 apartments were pre–assessed twice with glue traps prior to the trial. Pre-counts allow treatments to be evenly distributed between the intensities of infestations. All treatments had high, medium and low infestations. Ten apartments each were used for the three treatments. Six apartments were left as untreated controls. Dosage of product was according to label: 1 spot of 200 mg bait per m² kitchen area in cases of low and medium infestations, 2 spots of 200 mg in cases of high infestation. layout of all kitchens was identical, apartments received 15 or 30 spots of 200 mg depending on infestation.

Cockroach populations were assessed by glue traps at the indicated time intervals. % reduction was calculated in comparison of the pre-treatment counts (% reduction = $(P_{pa} - P_a)/P_{pa}*100$ where P_{pa} is pre-assessment counts (mean of -14D and -7D) and P_a is assessment counts. Trap catches were also analyzed with respect to life cycle stages to calculate the nymph-to-total ratio (NTR). Counted numbers of lifecycle stages were aggregated across the replicates of each treatments and each observation point, then: $NTR= N_{nymphs}/(N_{nymphs}+N_{adults})$. We chose this method over calculating individual NTR per replicate as several trap catches did not contain both life cycles stages.

RESULTS

Simulated-use trials. The experimental gel with 2.15% Imidacloprid, 5% flexible capsules containing a feeding stimulant was first assessed in small arenas in the laboratory. Mortality rates and dynamics of the lethal effect were comparable to standard Imidacloprid containing products such as MaxForce White IC (data not shown). To further assess the performance, trials were carried out in simulated use trials in which 7.5 m² compartments were allowed to populate with *B. germanica* populations as described above. Reduction of population could not be calculated as we did not want to impact the population with trap catches, instead dead cockroaches were counted at each of the observation periods. We observed similar numbers of dead adults between the two treatments of our standard Maxforce White IC and the experimental formulation with 238 and 317 killed imagines respectively (Table 1). In contrast, numbers of killed nymphs differed dramatically between the treatments. The experimental formulation killed by far more nymphs than the standard.

Without determination of the size of the population in those compartments via glue traps, reduction levels could not be calculated in these trials. In order to overcome this limitation, a larger field trial was planned and executed.

Table 1. Accumulated number of dead nymphs and adults of *B. germanica* after treatment with two different cockroach bait gels in simulates use trials.

	Number of dead insects									
	Adults					Nymphs				
Formulation	**1 d**	**2 d**	**3 d**	**1 w**	**2w**	**1 d**	**2 d**	**3 d**	**1 w**	**2w**
Maxforce White IC, 2.15% Imidacloprid	55	95	135	184	238	89	178	289	488	791
Experimental gel, 2.15% Imidacloprid containing 5% capsules with feeding stimulant	50	125	189	269	317	90	203	351	1757	2616
Untreated control	0	0	0	1	6	0	0	0	0	0

Table 2. Total reduction of cockroach populations after treatment with three different cockroach bait gels at the indicated time points.

	Day 3	**Day 7**	**Day 14**	**Day 28**	**Day 56**	**Day 91**
Maxforce White IC, 2.15% Imidacloprid	76 ± 10	94 ± 3	95 ± 3	95 ± 4	93 ± 7	88 ± 8
Experimental gel, 2.15% Imidacloprid containing 5 % capsules with feeding stimulant	80 ± 10	94 ± 6	97 ± 7	99 ± 3	99 ± 2	94 ± 4
Maxforce gel, 2.15% Hydramethylnon	71 ± 10	91 ± 5	93 ± 6	93 ± 5	92 ± 5	87 ± 8
Untreated control	1 ± 12	-3 ± 10	-4 ± 7	-1 ± 9	-7 ± 9	-9 ± 18

Field trials. Ten apartments, all identical in size and layout, were treated according to label either with Maxforce White IC (2.15% imidacloprid), Maxforce gel (2.15% hydramethylnon) or the experimental gel with 2.15% imidacloprid, 5% flexible capsules containing a feeding stimulant. All treatments showed a fast initial reduction in cockroach numbers ranging between 71 and 80% at day 3 after treatment (Table 2). Highest reduction numbers were achieved around 28 days after treatment for all products tested. At day 91, 3 months after treatment, reduction levels were still high for the experimental formulation but showing signs of increasing cockroach numbers in the other treatments.

The analysis of the age distribution of the remaining cockroach population revealed that firstly, the nymph-to-total ratio remained extremely constant in the untreated control populations at 0.61±0.037 and secondly, all populations showed the same ratio prior to treatment at 0.60±0.017. Treatment of these populations with conventional insecticidal cockroach baits has only a slight impact on this age structure as Maxforce White IC and Maxforce Gel, containing different mode of action insecticides, showed only slight increase in nymph-to-total ratio. In other words, those treatments resulted in slightly higher numbers of nymphs and fewer adults in the surviving population. In contrast, the experimental gel reduced the NTR amongst the survivors to a minimum of 0.14. This drastic effect is indicative of a preferential elimination of the larval stages in the population (Figure 1).

DISCUSSION

The data presented here show that a hydramethylnon- and a imidacloprid-based bait gel, while giving satisfactory general population reductions, do not change the nymph-to-total ratio (NTR) in a cockroach field population. In previous trials against field populations of *B. germanica* (Ameen et al., 1998) where fipronil and abamectin-based bait gels were tested in comparison to an IGR, the NTR also remained stable for fipronil- and abamectin-based gels whereas it was reduced for the IGR treatment.

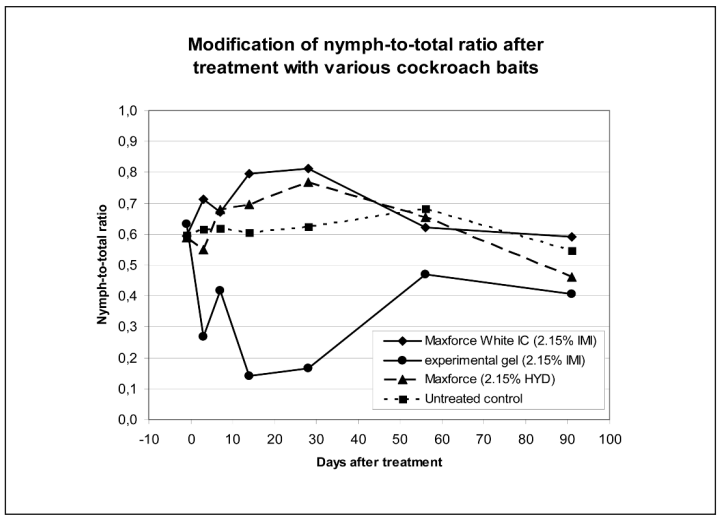

Figure 1. Modification of NTR in surviving *B. germanica* populations after treatment with different cockroach gels at the indicated time intervals.

The experimental bait gel with 2.15% imidacloprid and capsules containing specific feeding stimulants, while also giving excellent reductions of total cockroach number, additionally also decreased the percentage of nymphs in the population. Between week 1 and week 8 after treatment we saw the lowest values for the NTR ranging between 0.4 and 0.14; the percentage of nymphs in the trap catches was reduced up to 14%. This effect suggests an increased consumption of bait by nymphs at the bait spot. We rule out indirect effects such as secondary killing of larvae via feeding on dead carcasses or faeces as it is unlikely to encounter different copro- or necrophagic behaviour patterns in a single, multi-story apartment block.

The reason why we observed an increase of total cockroach numbers between month 2 and 3 after treatment across all apartments participating in the study can be attributed mostly to re-invasion from neighbouring apartments. A census in that building had shown widespread cockroach problems and we were able only to treat part of the entire building. Consequently, reinvasion is likely to occur rapidly (Runstrom and Bennett, 1990).

Elimination of nymphs is an essential aim of cockroach control as these stages are considered responsible to re-populate a location once all bait spots have been consumed or bait spots are rendered unpalatable. Near total removal of nymphs will therefore have a beneficial impact on the duration of acceptable control levels. From the conducted studies we conclude that the preferential elimination of larval stages is caused by the inclusion of the capsules containing a specific blend of feeding stimulants. A predicted consequence of this modulation is a long term inability for populations to recover.

The new imidacloprid gel has been developed by Bayer Cropscience AG and launched in Europe under the brand name Maxforce Fusion. Maxforce is a registered trademark of Bayer Cropscience AG.

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