Proceedings of the Tenth International Conference on Urban Pests
Rubén Bueno-Marí, Tomas Montalvo, and Wm. H Robinson (editors) 2022
CDM Creador de Motius S.L., Mare de Deu de Montserrat 53-59,
08930 Sant Adrià de Besòs, Barcelona, Spain

EFFECT OF DOSE MANIPULATION OF COMMERCIAL COCKROACH GEL BAITS ON THE MORTALITY OF *PERIPLANETA AMERICANA* (DICTYOPTERA: BLATTELLIDAE)

ELYSHA PATERSON AND SOPHIE THOROGOOD
The Power Centre, Rentokil Initial, Crawley, UK

Abstract Insecticidal baits are one of the most popular tools for controlling cockroaches. They rely on precise label dosage guidelines to achieve control for a varied number of cockroach species. *Periplaneta americana* can consume high quantities of bait before being incapacitated. This has the potential for a lethal dose only to be consumed by a subsection of the infesting population resulting in less efficient pest control and re-visits required to treat the remaining population as label bait guidelines are absolute, making it illegal to apply more than the label dose. In this study, the label doses of five commercially available cockroach baits (Advion, Goliath, Maxforce FC Magnum, PCI and Pesguard) were evaluated and manipulated to establish what amount of bait is needed to achieve mortality against *P. americana*. Only the primary mortality rate was evaluated to remove the factor of secondary mortality from horizontal transfer of bait. Advion was the only bait able to achieve 100% mortality at the label application rate; all other baits required increased dosage to achieve absolute mortality of *P. americana*.

Key words Bait, *Periplaneta americana*, dose manipulation, fipronil.

INTRODUCTION

Periplaneta americana has evolved to cohabit with humans and is one of the most prevalent pest species globally. *P. americana* is rife within sewers due to the high humidity and large availability of food and is able to infest dwellings from sewers all year round (Rierson et al., 2005). This species is able to survive on a wide variety of food (Schal et al., 1984) and withstand long starvation periods (Willis and Lewis, 1957), breed quickly and harbour in gaps; making cockroach control difficult. Control is a necessity as *P. americana* is associated with unsanitary habitats, unpleasant smells and most contributes to the transmission of over 20 human pathogens (Fakoorziba et al., 2010; Pai et al., 2005).

Sanitation is a fundamental measure of cockroach control; this will limit the availability of food and suppress the population (Mallis et al., 2011), although, eliminating all food sources is sometimes infeasible in urban environments. Consequently, integrated pest management (IPM) programmes will integrate sanitation and active tools to combat the pest; predominantly insecticides. Insecticidal bait is the choice tool to kill cockroaches; clean, efficient and can be applied in high risk areas (Rust, 1986; Dhang, 2018). Bait is a mixture of an attractive starchy food matrix and a small percentage of insecticide such as fipronil, imidacloprid, boric acid, hydramethylnon, indoxacarb or abamectin (Dhang, 2018; Mallis et al., 2011).

The insecticide used and its concentration are significant factors affecting the performance of the bait; however, the quantity of bait applied is also an important but overlooked factor. Srinivasan et al. (2005) demonstrated that fipronil (0.05%) based baits achieved better control against *Blattella germanica* than *P. americana* and bait label guidelines could be accountable. If on average, *P. americana* is 4 times as big as *B. germancia* (length 53 mm to 13 mm respectively) (Mallis et al., 2011), it will be capable of consuming larger quantities of food. Yet, label bait guidelines apply 1.5 - 2.5 times more bait for larger compared to smaller species of cockroaches, not aligning with the feeding habits of *P. americana* which readily consume high quantities on the first food source they find (Durier and Rivault, 200). Furthermore, many insecticides in baits are slow-acting (Mallis et al., 2011) hence, it is unlikely that a *P. americana* will be incapacitated before the cockroach either ceases feeding or all bait has been consumed. As such, the label dose guidelines may compromise effective *P. americana* control. In this study, five commercially available baits were evaluated at the label guideline along with five and ten times the label guideline to quantify the mortality rate of *P. americana*.

METHODS AND MATERIALS

Insects. *Periplaneta americana* were from an established laboratory colony at Crawley, UK; reared in a climate controlled room (27 ± 2°C and 60 ± 10% RH) with a 12:12 light/dark cycle. Water and rodent chow, RM1 (P), were provided *ad libitum.*

Baits. Five baits were analysed: Advion® (a.i.: Indoxacarb 0.6%) from Syngenta, Goliath® Gel (a.i.: fipronil 0.05%) from BASF, Maxforce® FC Magnum (a.i.: 0.05% fipronil) from Bayer (Maxforce, hereafter), PCI Gel (a.i.: fipronil 0.05%) from Pest Control India and Pesguard ® Gel (a.i.: clothianidin 0.5% and pyriproxyfen 0.5%) from Sumitomo Chemical.

Trial procedure. Continuous choice exposure method was used to evaluate bait efficacy. Baits were tested at the label, five times the label and ten times the label application rate for a high infestation of *P. americana* (Advion and Maxforce were only applied at the label and five times the label dose rate). The baits were not replenished once consumed. The arena, a steel tank (290 mm x 450mm) had the internal tank walls coated with PTFE water dispersion to prevent insects escaping. A harbourage, a cut piece of egg crate, was provided along with a water source. 10 mixed sex adults *P. americana* were introduced and allowed to acclimatise for 24 hours without food. After the acclimatisation period, cockroaches were assessed and any dead cockroaches were removed.

After acclimatisation, the bait (no bait was added for control) along with rodent chow was added; cockroach knock down and mortality was checked daily for 14 days after bait introduction, dead cockroaches were removed on a daily basis. Knock down = insect lacks coordinated movement and unable to right itself when turned over on its back. Dead = lack of movement and only slight movement if the insect was gently prodded.

Data analysis. Each condition was tested in triplicate, mean percentage mortalities half way through the trial period (day 7) were analysed with ANOVA using General Linear Model.

RESULTS

The time taken for total bait clearance was variable between the baits, Goliath and Pesguard were cleared for all bait dosages within 24 hours. PCI was only cleared at the label and five times the dose but all other bait applications had bait remaining by the end of the trial. The amount of bait applied was variable when adhering to bait label guidelines (range = 1.2596g between Advion and Goliath). There was a wide variance in the amount of fipronil (0.05%) applied, with Maxforce label guidelines having 38 times more active (g) than Goliath label, see Table 1. Goliath, PCI and Pesguard had the quickest initial knock down and PCI at ten times the label dose achieved 100% knock down in 2 days. At the label rate only Advion and Maxforce achieved 100% knock down in 8 and 9 days respectively (Table 2.)

At five times the label application rate all baits achieved 100% mortality, except Advion and Goliath which plateaued at 97% and 93% mortality respectively. The mortality curve of Advion and Maxforce remained similar with this increase in bait availability and mortality between the label and five times the label on day 7 were not significantly different for each other (Table 1). However, for Goliath, PCI and Pesguard the mortality rate accelerated by increasing the dose from the label to five times the label and the mean mortality at 7 days for these three baits were considered significantly different. A further improvement in mortality was shown by increasing Goliath and PCI from five to ten times the label bait dosage; conversely Pesguard demonstrated a decrease in mortality rate from this increase in bait application; these changes in mortality were not considered significantly different. There was no control mortality in any of the replicates. Only Advion achieved 100% mortality at the label application rate, however, Advion had a slow initial mortality (first mortality on day 3, Figure 1).

DISCUSSION

Rapid bait clearance of Goliath, PCI and Pesguard led to mortality stalling when applied at the label dose. At the label rate only 0.0135g and 0.036g of bait were applied for Goliath and PCI respectively, yet *P. americana* has a mean daily consumption rate between 0.0144 – 0.0183g (Wharton and Wharton, 1959). Consequently, it is likely that one cockroach was able to completely eat all bait placed for Goliath and half of the bait placed for PCI, leaving no bait or only sub lethal doses available for the remaining cockroaches. Srinivasan et al., (2005) also demonstrated less than adequate control (<80% mortality) for fipronil (0.05%), unless tested above the label application rate even against low densities of cockroaches ($5/m^2$).

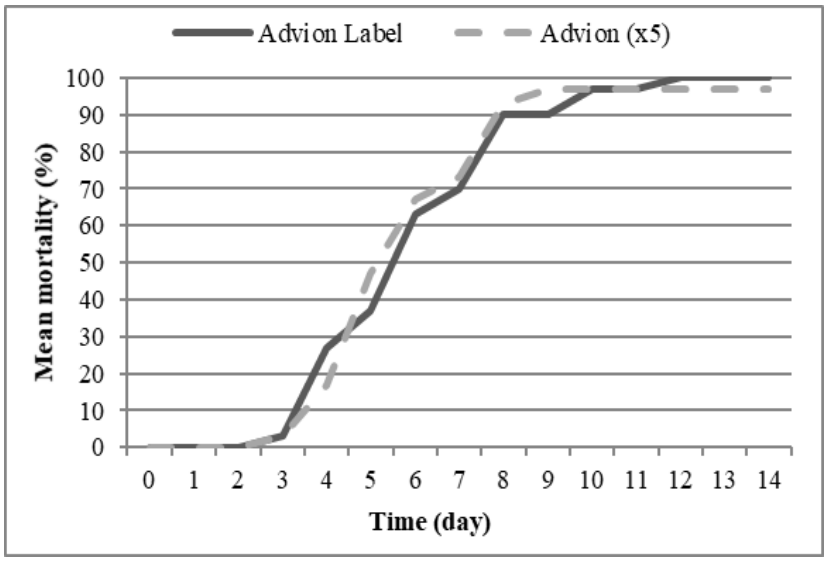
A significant increase in mortality was shown by increasing the label to five times the label dose for Goliath, PCI and Pesguard, but the mortality rate remained similar for Advion and Maxforce. The wide variance in amount of bait applied between Advion and Maxforce versus Goliath, PCI and Pesguard could be accountable. With larger

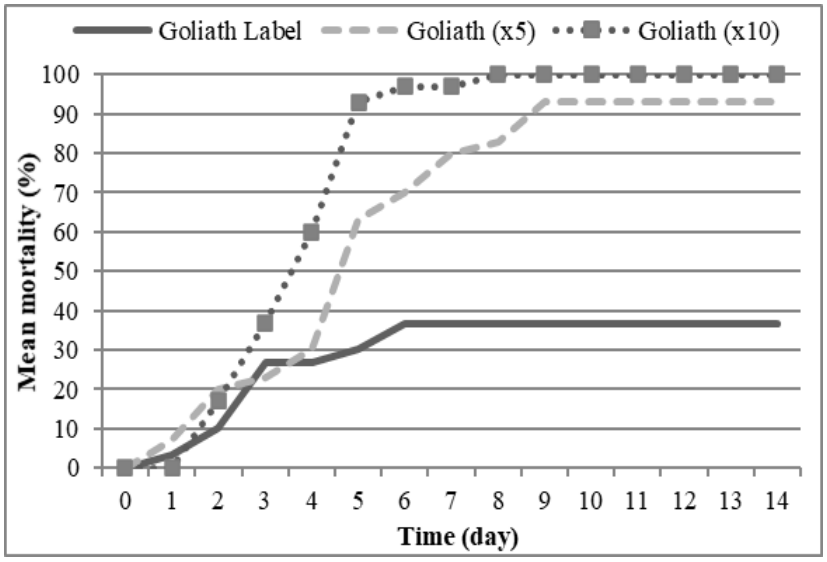
Table 1. Amount of bait and active applied (g) for each bait and dosage. Values followed by the same letter in the row or column were considered not significantly different from each other ($P < 0.05$).

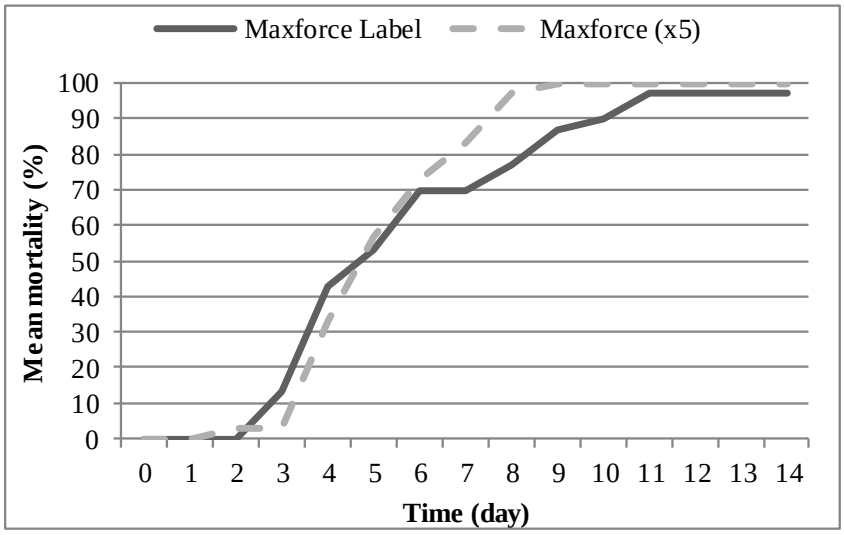
	Advion	**Goliath**	**Maxforce**	**PCI**	**Pesguard**
Application rate	5 x 0.5g/10ft	3 x 0.03g/m^2	3g/ sq yard	4 x 0.06g/m^2	10 x 0.032g/m^2
Amount applied at label (active applied)	1.2956g (0.007774g)	0.0135g (0.000007g)	0.5382g (0.000269g)	0.036g (0.000018g)	0.048g (0.00024g)
% Mortality after 7 days (Mean ± SD)	70 ± 0.20^{ab}	37 ± 0.06^{ac}	70 ± 0.10^{af}	43 ± 0.12^{a}	47 ± 0.25^{bcf}
Amount applied at 5x label (g) (active applied)	6.478 (0.038870)	0.0675 (0.000030)	2.691 (0.001350)	0.18 (0.000090)	0.24 (0.00120)
% Mortality after 7 days (Mean ± SD)	73 ± 0.15^{ae}	80 ± 0.17^{e}	83 ± 0.12^{ef}	83 ± 0.12^{e}	97 ± 0.06^{e}
Amount applied at 10x label (g) (active applied)		0.135 (0.00010)		0.36 (0.00020)	0.48 (0.00240)
% Mortality after 7 days (Mean ± SD)		97 ± 0.06^{de}		100 ± 0.00^{de}	83 ± 0.12^{de}

Table 2: Mean percentage knock down of cockroaches by day after bait placement.

	Mean knock down (%) of each bait by day														
Bait	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Advion Label	0	3	33	50	80	83	87	93	100	100	100	100	100	100	100
Advion (x5)	0	0	13	33	57	63	83	87	100	100	100	100	100	100	100
Goliath Label	0	13	28	27	35	37	37	37	37	37	37	37	37	37	37
Goliath (x5)	0	43	77	77	90	93	93	93	93	93	93	93	93	93	93
Goliath (x10)	0	53	87	93	97	100	100	100	100	100	100	100	100	100	100
Maxforce Label	0	0	27	73	90	93	97	97	97	100	100	100	100	100	100
Maxforce (x 5)	0	3	60	100	100	100	100	100	100	100	100	100	100	100	100
PCI Label	0	20	50	53	57	57	57	60	60	63	63	63	67	70	73
PCI (x5)	0	30	73	87	90	97	97	97	97	97	97	97	97	97	100
PCI (x10)	0	70	100	100	100	100	100	100	100	100	100	100	100	100	100
Pesguard Label	0	13	33	37	50	50	50	50	50	50	50	50	50	50	50
Pesguard (x5)	0	43	67	77	90	100	100	100	100	100	100	100	100	100	100
Pesguard (x10)	0	30	73	90	97	100	100	100	100	100	100	100	100	100	100


Advion Label
Advion (x5)
Mean mortality (%)
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Time (day)


Goliath Label
Goliath (x5)
Goliath (x10)
Mean mortality (%)
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Time (day)


Maxforce Label
Maxforce (x5)
Mean mortality (%)
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Time (day)

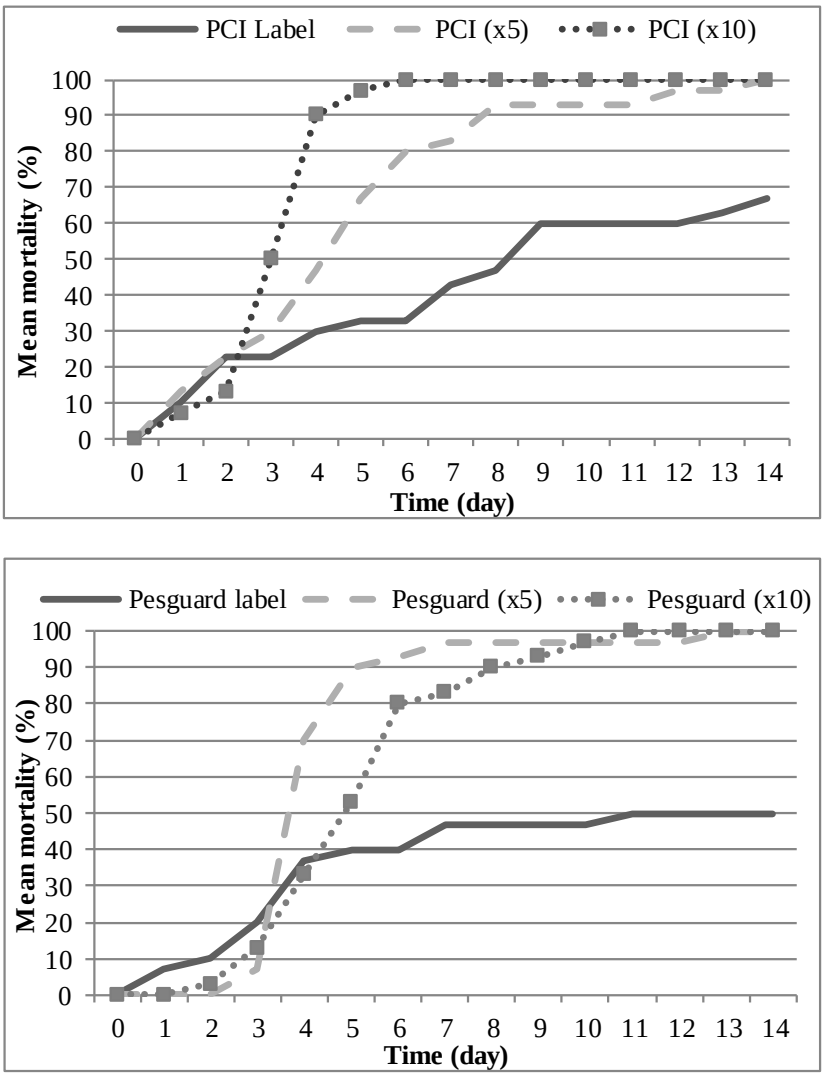


Figure 1. Mortality of *Periplaneta americana* against A: Advion (0.6% indoxacarb), B: Goliath (0.05% fipronil), C: Maxforce (0.05% fipronil), D: PCI (0.05% fipronil) and E: Pesguard (0.5% clothianidin and 0.5% pyriproxyfen).

amounts of bait applied, *P. americana* consumption would be more likely to be fulfilled at the label dose and so increasing the dose would lead to no more bait being consumed and the mortality remaining similar, furthermore, there was bait left behind at the label dose for Advion and Maxforce which supports this theory. Anikwe et al., (2014) also demonstrated that the mortality rate was not correlated with the amount of Advion applied (0.25g, 0.5g and 1.0g). However, at five times the label dose for Goliath, PCI or Pesguard the average daily consumption is more likely to be fulfilled, thereby increasing the chance that each cockroach was able to consume a lethal dose. A further increase of bait to ten times the label dose did not confer a significant change in mortality; this is likely because only a smaller amount of extra feeding occurred as the consumption requirements were more likely to align with five times the label dose.

Maxforce had a delay in initial mortality compared to other fipronil (0.05%) based baits. While fipronil does not repel cockroaches (Durier and Rivault 2000) it can reduce feeding in large quantities. However, the bait matrix of Maxforce is more likely to be less attractive and less palatable than the other baits, thereby slowing the feeding rate and delaying the mortality. Advion also had a slower initial mortality; this aligns with Syngenta statement that Advion allows cockroaches to return to harbourages before death, resulting in secondary mortality (Syngenta, 2017). Still, the

mortality rate shown in this study (100% mortality in 12 days) was slower than previous evaluations of indoxacarb (0.6%) where 100% mortality was recorded within 24-96 hours (Anikwe et al., 2014), 24-60 hours (Ctgb, 2010) and 72-96 hours (Scherer et al., 2005). There may be a discrepancy in how knockdown and mortality are counted between the trials, leading to the mortality rate being slower in this study. Nevertheless, there was only 50% knock down in 72 hours and 100% knock down in 8 days for cockroaches in this study, a slower knock down rate demonstrated in previous studies.

Lack of efficacious control of *P. americana* with label bait applications could compromise control strategies in the field, making it necessary for multiple visits to reduce the standing population to zero. This study solely focused on primary mortality but it is widely known that many baits cause horizontal mortality (Buczkowski et al., 2008), (Buczkowski and Schal 2001). However, good, clean pest control should remove cadavers and thereby reduce the effects of horizontal bait transfer. What's more if cockroach control becomes reliant on secondary mortality, this could incur resistance in the future from cockroaches continually eating sub lethal doses of insecticide.

The manipulation of bait application rates is not appropriate in the field; this will subsequently pressure technicians to choose baits that allow a larger quantity of bait to be applied for controlling American cockroaches more effectively. Yet, other baits will be as efficacious if a larger quantity of bait applied. This is not necessarily due to increasing the amount of insecticide placed, but rather by satisfying the appetite of the cockroach. Fipronil is highly toxic to cockroaches, with minimal amounts needed to be consumed to induce mortality (Valles et al., 1997). In fact, a similar level of efficacy was demonstrated for 0.05% and 0.01% fipronil baits against *P. americana* (Bayer et al., 2012), with the author stating in general, more insecticide was consumed by cockroaches that was required to cause mortality. Decreasing the insecticide percentage while increasing the amount of bait matrix will prevent cockroaches consuming super lethal doses of active, the most expensive component of the bait and lead to more sustainable and efficient pest control.

REFERENCES CITED

Anikwe, J. C., Adetoro, F. A., Anogwih, J. A., Makanjuola, W. A., Kemabonta, K. A. and Akinwande, K. L. 2014. Laboratory and Field Evaluation of an Indoxacarb Gel Bait Against Two Cockroach Species (Dictyoptera: Blattellidae, Blattidae) in Lagos, Nigeria. Journal of Economic Entomology, 107(4), 1639–1642. doi:10.1603/ec13457

Bayer, B.E., Pereira, R.M. and Koehler, P.G., 2012. Differential consumption of baits by pest blattid and blattellid cockroaches and resulting direct and secondary effects. Entomologia Experimentalis et Applicata, 145(3), pp.250-259.

Buczkowski, G., Scherer, C. W. and Bennett, G. W. 2008. Horizontal Transfer of Bait in the German Cockroach: Indoxacarb Causes Secondary and Tertiary Mortality. Journal of Economic Entomology, 101(3), 894–901. doi:10.1093/jee/101.3.894

Buczkowski GRJ and Schal C. (2001). Emetophagy: fipronil-induced regurgitation of bait and its dissemination from German cockroach adults to nymphs. Pestic Biochem Physiol; 71 : 147-55.

Ctgb.blob.core.windows.net. (2010). *Product Assessment Report*. [online] Available at: https://ctgb.blob.core.windows.net/documents/7529141716deb24ddfabc9a9cf117afc_20100816_13434_01.html#_Toc287365611 (2 Feb. 2020).

Dhang, P. 2018. Urban Pest Control A Practioner's Guide. Boston, MA: CABI, 98-99 pp

Durier, V. and Rivault, C. 2000. Comparisons of toxic baits for controlling the cockroach, *Blattella germanica*: attractiveness and feeding stimulation. Medical and Veterinary Entomology, 14(4), 410–418. doi:10.1046/j.1365-2915.2000.00259.x

Fakoorziba, M. R., Eghbal, F., Hassanzadeh, J. and Moemenbellah-Fard, M. D. 2010. Cockroaches (*Periplaneta americana* and *Blattella germanica*) as potential vectors of the pathogenic bacteria found in nosocomial infections. Annals of Tropical Medicine & Parasitology, 104(6), 521–528. doi:10.1179/136485910x12786389891326

Mallis, A. 2011. Handbook of Pest Control. Cleveland, Ohio: Franzek & Foster. 176-225 pp. 10th ed

Pai, H.H., Chen, W.C. and Peng, C.F. 2005. Isolation of bacteria with antibiotic resistance from household cockroaches (*Periplaneta americana* and *Blattella germanica*). Acta Tropica, 93(3), 259–265. doi:10.1016/j.actatropica.2004.11.006

Reierson, D.A., Rust, M.K, and Paine, E. 2005. Control of American (Dictyoptera: Blattidae) in sewer systems. *In*: Proceedings of the 5th International Conference on Urban Pests. (Lee, C-Y. and W.H. Robinson, Eds.) Perniagaan Ph'ng P&Y Design Network, Malaysia. pp.141-148.

Rust, M. K. and Reierson, D.A. 1981. Attraction and performance of food materials in insecticidal baits for German cockroach control. International Pest Control 23: 106–109

Scherer, C. W., Sandell, L.S. and McClurg. E.L. 2005. Indoxacarb as a new active ingredient for the pest control industry: Development of a cockroach gel bait as a case study, p. 551. In C. Y. Lee and W. H. Robinson [eds.], Proceedings of the Fifth International Conference on Urban Pests, 10 Đ13 July 2005. P and Y Design Network, Suntec, Singapore

Srinivasan, R., Jambulingam, P., Subramanian. S. and M. Kalyanasundaram. 2005. Laboratory evaluation of fipronil against *Periplaneta americana* & *Blattella germanica*. Indian J. Med. Res. 122: 57–66.

Syngenta.com. 2017. Available at: http://www.syngentapmp.com/imagehandler.ashx?ImID=bcf5b04e-a896-4f92-9f25-56e8403e7431&fTy=0&et=8 (3 Feb. 2020).

Valles, S. M, Koehler, P. G. and Brenner, R. J. 1997. Antagonism of fipronil toxicity by piperonyl butoxide and S,S,Stributyl phosphorotrithioate in the German cockroach (Dictyoptera: Blattellidae). J. Econ. Entomol. 90: 1254-1258.

Wharton, D. R. A. and Wharton, M. L. 1959. The Effect of Radiation on the Longevity of the Cockroach, Periplaneta americana, as Affected by Dose, Age, Sex and Food Intake. Radiation Research, 11(4), 600. doi:10.2307/3570814

Willis, E. R. and Lewis, N. 1957. The Longevity of Starved Cockroaches. Journal of Economic Entomology, 50(4), 438–440. doi:10.1093/jee/50.4.438