Susceptibility of British head lice, Pediculus capitis, to imidacloprid and fipronil

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Susceptibility of British head lice, *Pediculus capitis*, to imidacloprid and fipronil

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Abstract. The head louse, *Pediculus capitis* De Geer (Phthiraptera: Pediculidae) has developed resistance to organochlorines, the organophosphate malathion and to pyrethroids in the U.K. Therefore, headlice from Bristol school children were bioassayed against two new insecticides, fipronil and imidacloprid. *Pediculus capitis* was fully susceptible to imidacloprid, but it required a relatively high dose and acted slowly. Fipronil acted faster at lower dose, but seemed to be affected by cross-resistance in a small proportion of *P. capitis*.

Key words. *Pediculus capitis*, *P. humanus*, body lice, cyclodiene resistance, fipronil, head lice, imidacloprid, lindane, malathion resistance, permethrin resistance, U.K.

Resistance of the head louse, *Pediculus capitis* De Geer, to the original organochlorine insecticides, DDT and lindane, is widespread (Gratz, 1997), while resistance to pyrethroid insecticides (permethrin and fenothrin) has been detected recently in the Czech Republic, France, Israel and the U.K., with anecdotal reports from the U.S.A. (White & Walker, 1995; Downs et al., 1999a). Resistance to the organophosphate malathion also has been reported in France (Izra & Brière, 1995). By insecticide exposure tests of isolated head lice, combined with a clinical trial of over-the-counter preparations (Downs et al., 1999b), resistance to both classes of insecticides has also been confirmed in the U.K. Thus carbaryl, a carbamate, is the only fully effective insecticide currently available in the U.K. for the treatment of pyrethroid-malathion resistant head lice. As carbaryl has recently been confined to prescription only medication in the U.K. (Boulton, 1995; DoH, 1995), there is a need for new products to treat infested patients. Therefore, the efficacy of two novel insecticides, fipronil and imidacloprid (Tomlin, 1997), which are widely used for flea control, was tested on human head lice.

For bioassay tests of insecticide susceptibility in vitro (WHO, 1981), papers were impregnated with fipronil or lindane by dipping pieces of Whatman GF/A glass microfibre paper (cut to 5 cm diameter) in a range of insecticide concentrations in isopropanol solution. Imidacloprid impregnated filter papers were made by dipping pieces of Whatman no. 1 cellulose filter paper (5 cm diameter) in insecticide dissolved in acetone: olive oil mix at a ratio of 3:1. Lindane was purchased from Sigma (Gillingham, Dorset, U.K.), fipronil (Frontline®, Rhône-Poulenc, West Malling, Kent, U.K.) and imidacloprid (Advantage®, Bayer, Newbury, Berks, U.K.) were commercial spot-on formulations. Insecticide stability and reproducibility of results were assessed by comparing the mortality of artificially reared cat fleas, *Ctenocephalides felis* (Bouché) (Pulicidae: Siphonaptera), on freshly made impregnated papers and papers stored at 4°C in the dark for 2 weeks. Laboratory-reared body lice, *Pediculus humanus*, of the Culicoides (1948) strain (Zeichner, 1999), fully susceptible to all insecticides were tested in parallel. Head lice were collected from Bristol schoolchildren (aged 4–11 years old) in 1998. Separate tests on samples of these head lice showed them to be resistant to permethrin and malathion in 1997 (Downs et al., 1999b). There was a lower mortality of head lice compared to susceptible body lice with malathion and permethrin exposure (*P*<10^6) and only a 36% mortality of head lice exposed to 10 g/100 ml of malathion and a 6% mortality of head lice exposed to 5g/100 ml of permethrin. This was further confirmed with an 82% failure rate for permethrin and a 64% failure rate for malathion on supervised topical treatment of infested schoolchildren. Consent for collecting head lice was obtained from the south and west local research ethics committee, the school head teacher and the children’s parents. A school nurse supervised during all head lice collections. Live adult head lice were collected using a fine-toothed louse comb and stored in a portable incubator for up to 2 h before testing.

Randomly selected healthy lice were placed on insecticide paper (maximum 10 lice per paper) for 2 h exposure, in an incubator maintained at 70% relative humidity and 30°C. After
2 h, half the lice were removed and placed on untreated dry papers, to see if there was any recovery after short exposure. The other lice remained on the impregnated papers for a further 22 h, up to a total of 24 h exposure. Morbidity and mortality rates were scored at the end of 2 h or 24 h exposure periods, respectively. Morbidity or death of each louse was judged by an absence of all internal and external movements.

After 24 h exposure to untreated control papers, there was no mortality of body or head lice on dry cellulose filter papers. On dry glass fibre paper, 2.5% of the control body lice died after 24 h exposure, possibly due to dehydration on this hygroscopic material. Even so, it was concluded that test procedures caused negligible mortality within 24 h. Results of tests with fleas (data not shown) confirmed the stability of both fipronil and imidacloprid on filter papers for at least 2 weeks. The results of the tests on body and head lice are given in Table 1.

Bioassays demonstrated that fipronil kills human body lice, with 100% mortality following 2 h exposure to 0.016% or more. However, not all head lice were killed despite using increased concentrations of fipronil up to 0.25% with 2 h exposure. Cross-resistance in dieldrin-resistant fruit flies (Hosie et al., 1995) and houseflies (Deng et al., 1991) extends to lindane and fipronil. Likewise, cyclodiene resistance in the mosquito Anopheles gambi $	ext{c}$ Giles (Diptera: Culicidae) can confer cross-resistance to fipronil (Brooke et al., 2000). As lindane-resistant head lice have been reported extensively (Kucirka et al., 1983; Gratz, 1997), the survival of some head lice, but not body lice, in fipronil (3–5%) and lindane (4–21%) seems to indicate that lindane-resistant phenotypes are still present in Bristol head lice populations, with potential cross-resistance to fipronil. If this is correct, development of fipronil for head lice control would not be advisable, despite the efficacy of fipronil against the dog louse, Trichodectes canis (De Geer) (Phthiraptera: Trichodectidae) (Coops & Penhaligon, 1997). Fipronil was only partly effective against multi-resistant fleas on cats, whereas imidacloprid was fully effective (Barratt & Schein, 1996). A useful feature of fipronil is its persistence in the skin, which could prevent re-infection for weeks (Cochet et al., 1997). One disadvantage of fipronil for use against human head lice could be that lindane undergoes photodegradation to desulfynylfipronil, which despite being just as effective against insects, is 10 times more toxic than fipronil to mammals (Hainzl & Casida, 1996).

Table 1. Rates of morbidity (2 h) and mortality (24 h) of Pediculus humanus and P. capitis exposed to different concentrations of imidacloprid, fipronil and lindane. Significant recovery of body lice was observed at 22 h following exposure for 2 h to imidacloprid 0.05% (\(P=0.13\); 0.1% (\(P=0.001\)); and 0.2% (\(P<10^{-5}\);) \(x^2\) or Fisher’s exact test.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Concentration (%)</th>
<th>Nos</th>
<th>%</th>
<th>Nos</th>
<th>%</th>
<th>Nos</th>
<th>%</th>
<th>Nos</th>
<th>%</th>
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<tr>
<td>Untreated controls</td>
<td>Glass paper</td>
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<td>0</td>
<td>0/49</td>
<td>0</td>
<td>–</td>
<td>–</td>
<td>2/80</td>
<td>2.5</td>
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<tr>
<td></td>
<td>Filter paper</td>
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<td>0</td>
<td>0/50</td>
<td>0</td>
<td>–</td>
<td>–</td>
<td>0/65</td>
<td>0</td>
</tr>
<tr>
<td>Imidacloprid</td>
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<td>–</td>
<td>–</td>
<td>0/49</td>
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<td>–</td>
<td>–</td>
<td>0/46</td>
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<tr>
<td></td>
<td>0.013</td>
<td>–</td>
<td>–</td>
<td>0/35</td>
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<td>–</td>
<td>–</td>
<td>0/46</td>
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<td>–</td>
<td>–</td>
<td>1/41</td>
<td>2</td>
<td>0/21</td>
<td>0</td>
<td>3/35</td>
<td>9</td>
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<td></td>
<td>0.05</td>
<td>–</td>
<td>–</td>
<td>10/34</td>
<td>29</td>
<td>10/17</td>
<td>18(a)</td>
<td>41(b)</td>
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<tr>
<td></td>
<td>0.1</td>
<td>30/50</td>
<td>60</td>
<td>32/55</td>
<td>58</td>
<td>7/25</td>
<td>28(b)</td>
<td>20/27</td>
<td>74(b)</td>
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<td></td>
<td>0.2</td>
<td>57/58</td>
<td>98</td>
<td>50/55</td>
<td>91</td>
<td>10/28</td>
<td>36(b)</td>
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<td>100</td>
<td>60/60</td>
<td>100</td>
<td>12/30</td>
<td>40(b)</td>
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<td>95</td>
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<td>24/24</td>
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<td>59/61</td>
<td>97</td>
<td>50/50</td>
<td>100</td>
<td>25/25</td>
<td>100</td>
<td>25/25</td>
<td>100</td>
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<td>–</td>
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<td>–</td>
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<tr>
<td></td>
<td>0.4</td>
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<td>96</td>
<td>–</td>
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(Jacobs et al., 1997). This suggests that it would make a very effective treatment for head lice on humans and could prevent re-infestation over a considerable period of time. Further studies on the efficacy of imidacloprid for general use as a pediculocide would appear justified, considering its relatively benign toxicological profile for mammals (Tomlin, 1997) combined with rapid knockdown of insects (Chao et al., 1997).

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