Insecticide resistance in sheep blowfly larvae

The development of resistance allows individual insects to survive an exposure to insecticide that would kill individuals from a 'normal' population. The sheep blowfly, *Lucilia cuprina* has developed resistance to at least three classes of insecticides that have been used to treat or prevent flystrike on sheep.

Resistance can evolve in two ways.

In the first way individuals that are naturally more tolerant of an insecticide within the normal population will survive when the concentration of insecticide in the wool drops below a marginally-effective level. The more susceptible types succumb and the more tolerant types survive.

In the second way mutations occur in individual insects that allow them to survive exposure to an insecticide at a time when normal insects die. Either way, a proportion of the insect population survives at the expense of another thus increasing the representation of the 'resistant' types.

Resistance development in *Lucilia* has arisen by the second means but, in the case of the organophosphates once the mutation was established in the population it is thought that the first type of evolutionary process came into play to enhance resistance even further.

The history of insecticide use and resistance development in sheep blowfly is outlined in the Table 1. For simplicity insecticides applied to wool to control any of the ectoparasites are listed with accompanying comments specifically addressing implications for flystrike control. Some noteworthy features are:

- The banning of organochlorines for use on sheep was due to residues in meat, not resistance although resistance was widespread by this time.
- Most wool producers did not recognise resistance to the organophosphates (OPs) because control failures due to poor application were commonplace.
- In the absence of alternatives, by 1970 most blowfly populations were comprised of 98% OP resistant larvae and this situation remains true today.
- OP resistance reduced the period of flystrike protection to only a few weeks, despite fleece residues remaining high for several months. Resistance also reduced the effectiveness of flystrike dressings.

- Treatments applied to control lice infestations have contributed to selection for resistance in sheep blowflies.
- Over the years resistance development has been responsible for the withdrawal of several flystrike products.
- Despite common usage since 1979 no resistance to cyromazine has been detected and there is no resistance to the more recently introduced compounds dicyclanil, ivermectin or spinosad.

There are several possible explanations as to why cyromazine has escaped resistance since 1979. One is that it has no activity against sheep lice and so has not usually been applied twice in a growing season. There is no doubt that repeat applications of organochlorines and organophosphate products targeting lice in short wool and blowflies in long wool increased the selection pressure for resistance. Dual use against lice and blowflies is also likely to have exacerbated resistance to the benzoylphenyl urea insect growth regulator diflubenzuron (Magnum®, Stampede®, Clik Plus®, Magic®, Fleececare®, Strike®) in sheep blowfly larvae, but there was also an influence from existing OP resistance. This resistance conferred low-level 'cross-resistance' to diflubenzuron. Low-level cross-resistance shortened the period of protection provided by diflubenzuron by about half but in 2002 reports of spectacular failures with diflubenzuron jetting products occurred. In the first of these investigated, sheep had become susceptible to flystrike immediately after being jetted with diflubenzuron! Laboratory tests confirmed a new high-level resistance with 50% of larvae unaffected by diflubenzuron irrespective of concentration. Over the next few years resistance was detected in widely-distributed populations of sheep blowfly with reports of failures with both spray-on and jetting formulations of diflubenzuron. In 2008 claims for flystrike protection were removed from product labels.

Laboratory tests demonstrated that diflubenzuron/OP resistant blowfly larvae are susceptible to cyromazine, dicyclanil, ivermectin and spinosad. This does not imply that these four insecticides are equally effective – they are not. It simply means that resistance from OPs and/or diflubenzuron has no influence on the effectiveness of the other insecticides against sheep blowfly larvae. It also means that woolgrowers have products available to them capable of providing long-term flystrike protection and products capable of controlling active flystrike.

The description of resistance development outlined above may suggest that resistance is the inevitable consequence of using insecticides. It is not. As the situation for cyromazine highlights, resistance may not develop. However, as any of the producers confronted with diflubenzuron resistant blowflies will attest, life is easier without resistance. Blowfly resistance should be suspected if the flystrike protection achieved after a preventative mob treatment is significantly less than the expected protection period. There are a number of management strategies

that wool producers can adopt to minimise resistance selection with a view to avoiding, or at least delaying the onset of resistance.

- Adopt an integrated pest management strategy that incorporates non-chemical controls such as genetic selection and timing of shearing and crutching to reduce the reliance on chemicals. Only use insecticides when absolutely necessary. This reduces selection pressure.
- If treatment is needed, make sure it is applied effectively - do it right, once!
- Know which insecticides belong to which insecticide class. If treatments for lice and flystrike are deemed necessary, use different insecticide classes for each pest. Use the Table 1 and the flyboss tool (product listing) to ensure that you are using different classes of chemical for flystrike and lice treatment.
- Also use insecticides from different classes for treating and preventing flystrike. This is particularly important if relying on insecticides to kill larvae on flystruck sheep. It is important to break the cycle and ensure maggots on struck sheep do not survive. Non-insecticidal methods are more reliable than flystrike dressings for this purpose. Dressings are mainly to prevent re-strike.
- Be aware that resistance to one insecticide may cause a cross-resistance to another related insecticide.

As with all chemical treatments, follow the label directions and keep a record of the product (including batch number), dose rate, date of treatment and mob treated, for future reference. Report adverse outcomes (product failures) to the company and to the Australian Pesticides and Veterinary Products Authority (APVMA).

Table 1. History of insecticide use and resistance development in Australian sheep blowfly populations.

Insecticide class	**Examples of insecticides in this class used to treat ectoparasites on sheep[1]**	**Year introduced for use on sheep[1]**	**Year resistance detected in blowfly**	Practical effect of resistance
Arsenical	arsenic trioxide	1919-1946	None detected	-
Other inorganic compounds	sulphur, rotenone, naphthalene, cresylic acid, copper sulphate, zinc sulphate, magnesium fluorosilicate	Some still available	None detected	-
Organochlorine	aldrin, dieldrin, BHC, DDT	1946-1958	1957	Flystrike protection completely lost. OCs were banned because of residues in meat.
Carbamate	butacarb	1966-1967	1967	Product withdrawn in 1967. Cross resistance to OPs and probably benzoyl phenyl ureas.
Organophosphate	diazinon, chlorfenvinphos, fenthionethyl, fenchlorvos, carbophenothion, propetamphos, coumaphos, malathion, trichlorfon	1957-some still available	1965	Flystrike protection reduced from approx. 18 weeks to only 2-4 weeks. Effectiveness of 'fly oil' type flystrike dressings greatly diminished.
Amidine	amitraz	Prior to 1987		-
Pyrethroids	cypermethrin, deltamethrin, cyhalothrin, cycloprothrin	1981- only one still available for flystrike control	None detected	-
Triazine	cyromazine	1979-	None detected	-
Benzoylphenyl ureas	diflubenzuron, triflumuron	1993	2001	Flystrike protection completely lost. Products withdrawn from use as flystrike preventatives.
Pyrimidine	dicyclanil	1998	None detected	-
Avermectin	ivermectin	1993-present	None detected	-
Spinosyn	spinosad	2003	None detected	-

[1.] Not necessarily for flystrike only. May have been used to control lice and/or itchmite and/or ticks as well.