

Insecticide resistance management of mites (*Tetranychus ludeni* Zacher and *T. urticae* Koch) in Australian cotton 1999-2001.

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Abstract

Effective resistance monitoring underpins the Australian cotton resistance management strategy for insects and mites. We present monitoring data for two-spotted mite, *Tetranychus urticae* Koch and bean spider mite, *Tetranychus ludeni* Zacher for cotton seasons 1999-2000 and 2000-2001. Abamectin (Wizard®), propargite (Comite®), diafenthiuron (Pegasus®) and chlorfenapyr (Intrepid®) resistance were not detected however there was a worrying reduction in chlorfenapyr dose-response slope values between seasons. Bifenthrin (Talstar®) resistance is increasing in both level and abundance in *T. urticae* but was not detected in *T. ludeni*. Profenofos resistance in *T. urticae* has dropped from a peak of 541x in 1999-2000 to 221x in 2000-2001 but would likely still give negligible control.

Introduction

The Insecticide Resistance Management Strategy (IRMS) for Cotton is designed to manage insecticide use, maintain the susceptibility of pest species to insecticides and to manage resistance where it already exists so that it does not become worse (Shaw 1999). One pest, the two-spotted spider mite is renowned for rapidly developing resistance to insecticides worldwide. In order to prevent this happening in cotton a mite-specific component has been developed in the IRMS. This strategy is based around two core principles (1) use limitations, ie a maximum of two applications of any product, and (2) rotation, ie. non-consecutive use of the same chemical. However, this can also be augmented by reducing the risk of mite outbreaks developing by; minimising the overwintering of resistant mites on weeds (Wilson, 1994a); controlling mites only when they are predicted to cause economic loss (Wilson, 1993); using more spider mites resistant varieties (Wilson, 1994b) and conserving beneficial insects (Wilson *et al.* 1998).

Monitoring is an integral part of the effective management of resistance in *T. urticae* in Australian cotton. Results of annual monitoring have chronicled the demise of the organophosphates and anticipated the need for newer chemistry (Herron *et al.* 1998; Herron *et al.* 2001). Here we present monitoring data for seasons 1999-2000 and 2000-2001 and discuss implications for future resistance management of mites.

Material and Methods

Strains Tested

Each year strains of mites *Tetranychus urticae* Koch (TSM) are collected from a range of sites across the cotton industry. These include areas where mites were a problem and were consequently subject to selection with miticides and sites where there were control failures or suspected control failures with miticides. Mites are taken to our laboratory at Camden where each strain is maintained separately on dwarf bean plants until tested for resistance.

Ten strains of TSM were collected in 1999-2000: -Y = Yuronah Field 32 Macquarie Valley, Co = Condraminer Toowoomba Darling Downs, NF2 = Colly Farms Field 136 Gwydir, W = Willawood Namoi Valley, Ku = Kurrabooma Field 1 Gwydir, Ka = Kamilaroi Field 7 Gwydir, Wa = Wambandry Field 40 Macquarie Valley, NF1 = Colly Farms Field 125 Gwydir, MV = Macquarie View Field 1 Macquarie Valley, Ty = Tyunga Toowoomba. Six strains of TSM were collected in 2000-2001: AE = Auscott Ewenmar, Macquarie Valley, EL = Ellengerah, Macquarie Valley, WH = White Acres Field 35, Macquarie Valley, NA = Carabeen, Namoi Valley, CU = Cubbaroo, Namoi Valley, MI = Milawa Field 1, Macquarie Valley. In addition, in 1999-2000 a strain of the bean

spider mite, *Tetranychus ludeni* Zacher (BSM), which is deep red in colour was also collected from Condraminer.

Chemicals Tested

Proprietary commercial formulations of profenofos (Curacron®), bifenthrin (Talstar®), abamectin (Agrimec®), propargite (Comite®), chlorfenapyr (Intrepid®) were used, except difenthiuron (Pegasus®). The UV activated carbodiimide derivative of diafenthiuron, CGA-140408 was tested.

Bioassay

Edge and James (1982) have described the bioassay procedure used in detail. Briefly, the method requires young adult female mites to be transferred from culture to French bean leaf discs. Mites and leaf disc are then sprayed with insecticide with the aid of a Potter spray tower. Each test is replicated and includes a water only sprayed control. For some products a dose/mortality line was generated to measure underlying changes in resistance factor, for other products a discriminating dose technique that kills susceptible but leaves resistant mites was used (the dose kills 99.9% of susceptible mites).

Analysis

Discriminating-dose tests were corrected for control mortality using Abbott's formula (Abbott 1925). Probit regressions were calculated for dose/mortality tests using Polo PC (Leora Software) and LC_{50} and LC_{99} values estimated. Resistance factors (RF) were calculated by dividing the dose that killed 50% of the susceptibles by the dose that killed 50% of the resistant strain.

Results

T. ludeni

Abamectin and bifenthrin resistance was not detected in *T. ludeni* (Table 1).

T. urticae

No resistance was detected to propargite or abamectin, as indicated by 100% mortality at the discriminating dose (Table 1). Similarly there was no resistance to chlorfenapyr or diafenthiuron as indicated by RF values approximately equal to one (Tables 2 and 3). Considerable negative cross-resistance was detected against chlorfenapyr (Table 2). This is particularly evident in strain MI with a RF of 0.09 making it more than an order of magnitude more susceptible to chlorfenapyr than the laboratory susceptible reference strain. Profenofos resistance during 1999-2000 was extreme (>500x)(Figure 1), however, resistance dropped to a maximum level of 221x in 2000-2001 (Figure 2). Bifenthrin resistance was common with 97% surviving the discriminating dose (3 % mortality) in one strain (Table 1).

Discussion

Profenofos resistance is currently lower than found previously. In 1999-2000 resistance exceeded 500x in the strains Willawood and Kamilaroi with another three strains having resistance at 200 – 300x. For the past 2000-2001 season resistance peaked at 221x in strain Carabeen with remaining strains having resistance levels <64x. Clearly, profenofos resistance is lower than it has been over the previous few seasons. However, profenofos resistance is still abundant and at high enough levels to cause field control of *T. urticae* to be negligible.

Slope values for chlorfenapyr are trending down season to season. A high slope is often associated with laboratory susceptible strains and indicative of susceptibility. However, a decline in the slope possibly reflects an increase in level of incipient resistance in the mites. When monitoring first started in 1997-1998 slope values were 3.0 – 4.1 (unpublished data). The following 1998-1999 season slopes had again dropped to 2.3 - 3.0 (unpublished data). Slopes continued to fall to 2.0 – 3.2 in 1999-2000 and for season 2000-2001 slopes are again lower and range from 1.7 – 2.7. Possibly the reduction in slope is

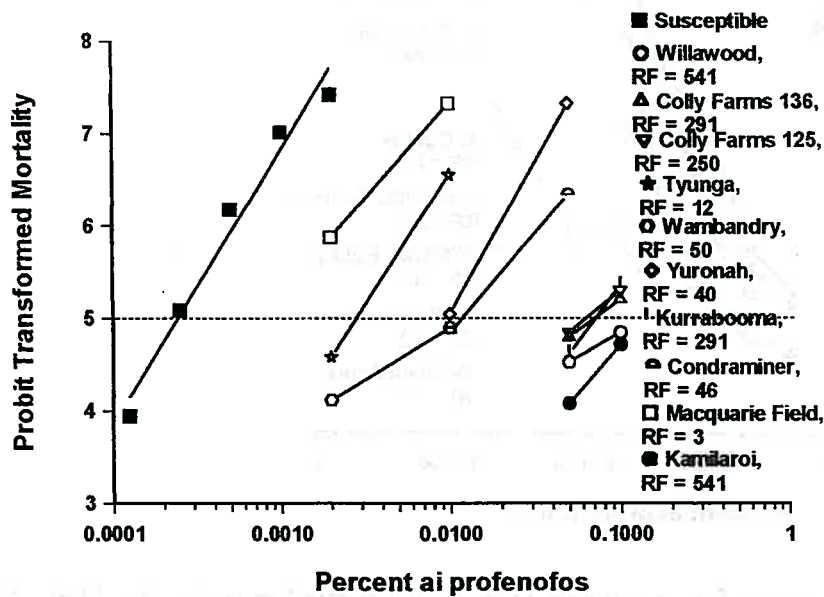


Figure 1 Dose-response testing for profenofos against two-spotted mite for the 1999/2000 cotton season (RF = resistance factor at LC_{50}).

related to negative cross-resistance. Negative cross resistance is actually caused by a resistance mechanism but in this instance making the chemical more rather than less toxic. Resistance to chlorfenapyr, resulting in control failures, has recently been reported in horticulture (unpublished data) after a single application of the product.

Herron *et al.* (2000) documented 33% bifenthrin resistant *T. urticae* in one population from the 1998-1999 season. By the 1999-2000 cotton season, bifenthrin resistance was detected in 9 of the ten strains tested with one population containing 80% resistant mites. Two strains, Colly Farms, field 125, Gwydir Valley and Colly Farms, field 136, Gwydir Valley, contained mites which survived 1.28 % bifenthrin, the highest rate that could be applied without severe phytotoxicity to the leaf disk. Clearly, bifenthrin resistance in *T. urticae* has now reduced the reliability of bifenthrin for mite control in Australian cotton. More control failures and very high-level resistance should be expect in following seasons.

The development of bifenthrin resistance flags an important problem for products targeted against more than one pest, as are most of the acaricides used in Australian cotton. For example, propargite is also used as a pyrethroid synergist against *Helicoverpa armigera*, abamectin is used against *H. punctigera*, diafenthiuron against aphids and chlorfenapyr against *Helicoverpa* spp. Obviously, use against other pests will also select for resistance in coincident *T. urticae* populations and visa versa, whether these are at economic levels or not. The next chemical group at risk is the avermectins. Emamectin-benzoate (Affirm®) has just been registered for use in Australian cotton for *Helicoverpa* control but also suppresses *T. urticae*. It is closely related to abamectin and use of one product is likely to impact on resistance selection by the other. To prolong the use of current chemicals for *T. urticae* control, we suggest Australian growers and cotton consultants need to consider all pesticide targets to reduce inadvertent acaricide selection.

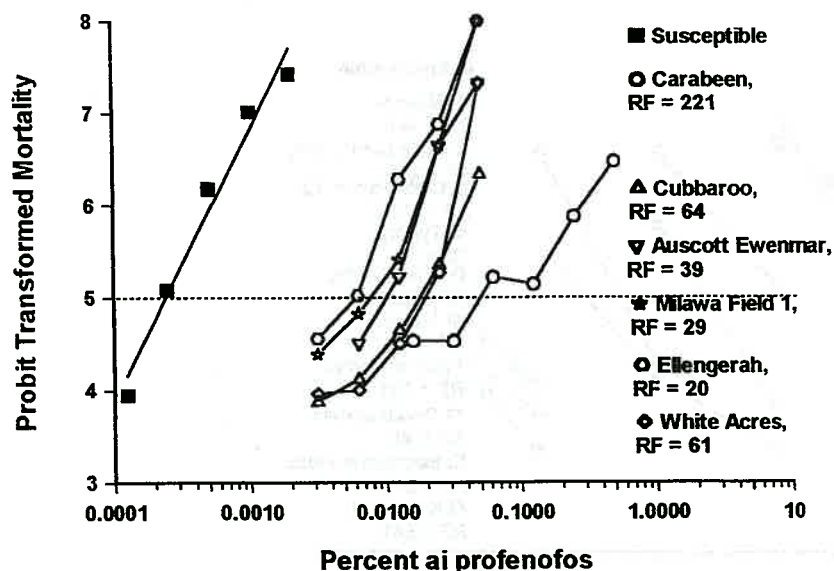


Figure 2. Dose-response testing for profenofos against two-spotted mite for the 2000/2001-cotton season (RF = resistance factor at LC₅₀).

Table 1. Testing results for the 1999/2000 and 2000/2001 cotton season- two-spotted mite (TSM) and one strain of bean spider mite (BSM) against a 0.01% discriminating dose (DD*) of propargite, 0.0001% DD of abamectin and 0.02 % bifenthrin

Year	Strain	Mortality at DD for bifenthrin	Mortality at DD for propargite	Mortality at DD for abamectin
1999/2000	TSM Y	92	100	100
1999/2000	TSM Co	100	100	100
1999/2000	TSM NF2	20	100	100
1999/2000	TSM W	65	100	100
1999/2000	TSM Ku	91	100	100
1999/2000	TSM Ka	86	100	100
1999/2000	TSM Wa	97	100	100
1999/2000	TSM NF1	84	100	100
1999/2000	TSM MV	94	100	100
1999/2000	TSM Ty	96	100	100
1999/2000	BSM Co	100	100	Not tested
2000/2001	TSM NA	3	100	100
2000/2001	TSM CU	40	100	100
2000/2001	TSM AE	90	100	100
2000/2001	TSM MI	56	100	100
2000/2001	TSM EL	96	100	100
2000/2001	TSM WH	100	100	100

* BSM was tested against a TSM DD

Table 2. Testing results for the 1999/2000 and 2000/2001 cotton seasons- two-spotted mite against chlorfenapyr.

Year	Strain	Slope	LC50 % ai	RF	LC99 % ai	RF
	Susc.	3.0 (0.46)	0.0017	-	0.010	-
1999/2000	TSM Y	2.0 (0.17)	0.00064	0.4	0.0095	0.9
1999/2000	TSM Co	2.8 (0.24)	0.00081	0.5	0.0055	0.5
1999/2000	TSM NF2	3.2 (0.28)	0.00068	0.4	0.0036	0.4
1999/2000	TSM W	2.9 (0.28)	0.00079	0.5	0.0050	0.5
1999/2000	TSM Ku	2.4 (0.21)	0.00070	0.4	0.0065	0.6
1999/2000	TSM Ka	2.0 (0.17)	0.00058	0.3	0.0084	0.8
1999/2000	TSM Wa	2.4 (0.24)	0.00074	0.4	0.0068	0.7
1999/2000	TSM NF1	2.1 (0.29)	0.0017	1.0	0.022	2.2
1999/2000	TSM MV	2.8 (0.54)	0.00029	0.2	0.0020	0.2
1999/2000	TSM Ty	2.4 (0.25)	0.00020	0.1	0.0019	0.2
2000/2001	TSM NA	2.7 (0.81)	0.00048	0.3	0.0035	0.4
2000/2001	TSM CU	2.7 (0.42)	0.00038	0.2	0.0028	0.3
2000/2001	TSM AE	1.8 (1.32)	0.00060	0.3	0.012	1.2
2000/2001	TSM MI	1.7 (0.36)	0.00015	0.09	0.0034	0.3
2000/2001	TSM EL	2.2 (0.59)	0.00027	0.1	0.0031	0.3
2000/2001	TSM WH	1.6 (1.56)	0.00053	0.3	0.015	1.5

Table 3. Testing results for the 1999/2000 cotton season- two-spotted mite against diafenthiuron

Year	Strain	Slope	LC50 % ai	RF	LC99 % ai	RF
	Susc.	5.9 (1.86)	0.00018	-	0.00034	-
1999/2000	TSM Y	3.4 (0.05)	0.00009	0.5	0.00017	0.9
1999/2000	TSM Co	4.1 (0.43)	0.00008	0.4	0.00030	0.9
1999/2000	TSM NF2	3.4 (0.32)	0.00007	0.4	0.00035	1.0
1999/2000	TSM W	1.8 (0.06)	0.00009	0.5	0.00025	0.7
1999/2000	TSM Ku	3.4 (0.30)	0.00007	0.4	0.00035	1.0

1999/2000	TSM Ka	3.8 (0.38)	0.00007	0.4	0.00026	0.8
1999/2000	TSM Wa	3.2 (0.47)	0.00011	0.6	0.00059	1.7
1999/2000	TSM NF1	3.7 (0.37)	0.00006	0.3	0.00027	0.8
1999/2000	TSM MV	4.0 (0.95)	0.00010	0.6	0.00038	1.1
1999/2000	TSM Ty	3.3 (0.34)	0.00009	0.5	0.00045	1.3
2000/2001	TSM NA	4.3 (0.75)	0.00022	1.2	0.00075	1.7
2000/2001	TSM CU	5.1 (0.85)	0.00024	1.4	0.00069	1.6
2000/2001	TSM AE	3.6 (0.85)	0.00017	0.9	0.00075	1.7
2000/2001	TSM MI	4.3 (0.68)	0.00023	1.3	0.00078	1.8
2000/2001	TSM EL	4.8 (0.78)	0.00022	1.2	0.00067	1.5
2000/2001	TSM WH	4.0 (1.56)	0.00016	0.9	0.00061	1.4

Acknowledgments

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10. The following table shows the number of people who attended the school sports day in 2020 and 2021.

Year 2020 2021
 Boys 120 150
 Girls 100 130

Calculate the percentage increase in the number of people who attended the school sports day from 2020 to 2021.

Answer: $\frac{150 + 130 - 120 - 100}{120 + 100} \times 100 = \frac{60}{220} \times 100 = 27.27\%$

11. The following table shows the number of people who attended the school sports day in 2020 and 2021.

Year 2020 2021
 Boys 120 150
 Girls 100 130

Calculate the percentage increase in the number of boys who attended the school sports day from 2020 to 2021.

Answer: $\frac{150 - 120}{120} \times 100 = \frac{30}{120} \times 100 = 25\%$

12.

The following table shows the number of people who attended the school sports day in 2020 and 2021.

Year 2020 2021
 Boys 120 150
 Girls 100 130

13.

The following table shows the number of people who attended the school sports day in 2020 and 2021.