Ignoring sorghum midge resistance can be costly

Despite significant advances in host plant resistance, many sorghum crops are still treated with insecticides to control midge. This case study examines the economics benefits of midge resistance under a range of pest pressure scenarios.

Globally, sorghum midge (*Stenodiplosis sorghicola*) is a major pest of sorghum. Females lay eggs into the sorghum flowers, and crop loss occurs from larvae feeding on the developing seed.

Midge density increases through summer, with later crops exposed to greater risk as midge populations build on successive plantings. Whilst early planting is a strategy for avoiding high midge pressure, in the largely dryland cropping system in which sorghum is grown, planting time is determined by rainfall. In some years, there may be successive sorghum plantings from September to January.

Sorghum midge are active from spring to autumn, and often first appear on Johnson grass (*Sorghum halepense*), where they breed for several generations before moving into sorghum crops at flowering. Female midge only live for a single day but can lay up to 50 eggs into sorghum flowers where larvae feed on the developing grain.

In summer the midge life cycle is typically 18-25 days; extremely high midge numbers can build-up over a growing season (particularly if the flowering period is extended by successive plantings). In a susceptible hybrid, the offspring of each female can destroy up to 1.4 g of grain. Large numbers can lead to devastating damage and in some cases, complete destruction of the crop.

Sorghum midge resistance breeding program

To combat the damage caused by sorghum midge, resistant hybrids were commercially introduced in the 1980s. Two types of midge resistance are available to breeders. The most common is 'ovipositional antixenosis', based on breeding for shorter, tighter glumes which make it difficult for the female to lay eggs into the flowers. The second mechanism is 'antibiosis' which causes the larvae to die so the grain then develops normally. Whilst the inclusion of midge resistance (MR) has reduced the impact of midge damage, not all resistance is equal. In the early 1990s a protocol was developed to measure the level of midge damage in commercial hybrids and assign an official MR rating. The rating number is a measure of the amount of grain lost per visiting female midge per day and ranges from 1 (no resistance) through to 8+ .

This rating is often used as a guide for growers when making planting decisions (especially later in the season). It can also be used when calculating the economic threshold (ET) during insect outbreaks, to determine if it is economically viable to spray.

All commercial sorghum varieties now have some level of midge resistance, but while the MR is often a consideration when late planting crops, it is regularly ignored when making midge spray decisions. An ET calculator is available to guide management decisions, but many growers and agronomists simply use the same 'rule-of-thumb' for all sorghum crops (i.e. 1 midge/head), regardless of the midge rating of the sorghum crop.

A significant opportunity therefore exists to more fully utilise the contribution of the midge resistance trait. This case study examines how to maximise the economic benefits of midge resistance under a range of scenarios.

Key findings

1. Glasshouse experiment showed synthetic pyrethroid's residual efficacy can be high up to 10 days post spraying. In the field however, head emergence is typically staggered, and even a day after spraying new emerging heads are susceptible to midge damage.
2. Varietal midge resistance (MR) provides significant economic benefits to growers in terms of the frequency that midge need to be treated with broadspectrum insecticides. There are also flow-on benefits of potentially reducing insecticide applications.
3. Ignoring the MR when treating midge is costing growers in terms of unnecessary insecticide applications, increased risk of secondary pest outbreaks, and selection for higher levels of resistance in midge and helicoverpa.
4. Industry has greatly benefited from the MR breeding program in sorghum, but there is marginal benefit in MR beyond 8+; future breeding may better serve the industry in concentrating on other agronomical traits whilst maintaining MR8+.

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Midge control practices

Chemical treatments are used to kill female midge before they can lay eggs. There are no selective/soft options currently available for midge control, and synthetic pyrethroids (SPs) are the most widely used insecticides. For example, the cost of control for lambda-cyhalothrin at 18–36 ml/ha is $3–6/ha plus an application cost of $5–15/ha (ground–air); this case study uses a total cost of $10/ha per treatment.

Although one insecticide application is often sufficient, under high and persistent midge pressure, three or four applications are not unusual. A crop that is highly tillered, or has uneven head emergence for other reasons, may be susceptible to midge damage over several weeks. Crops that are exposed to midge for longer will require repeated applications to minimise crop losses. Even though SPs have some residual activity on the crop, only the heads fully emerged at the time of spraying will be protected. The more staggered the flowering, the less benefit there is from residual insecticide efficacy.

Other management considerations

Integrated pest management for sorghum midge includes:

- earlier sowing (before mid-November) to avoid peak midge numbers that build up over the season
- managing Johnson grass to reduce midge populations moving into sorghum crops
- managing the crop (e.g. plant density, variety selection) for even flowering
- selection of MR sorghum varieties
- preserving natural enemies of midge and helicoverpa, through the use of well targeted and well-timed insecticide applications
- using appropriate ETs to guide chemical treatment decisions.

Natural enemies of both midge and other pests of sorghum such as helicoverpa, are killed by the use of broadspectrum insecticides such as SPs. *Helicoverpa armigera* has developed moderate to high levels of resistance to SPs, so incidental exposure to midge sprays (applied at lower rates than those effective against helicoverpa) exerts selection pressure for resistance in this pest.

The biopesticide NPV (nucleopolyhedrosis virus) is widely used in sorghum to control helicoverpa. The use of SPs for midge control, often in a tank mix with NPV, is highly disruptive to what would otherwise be an effective IPM strategy.

Economic thresholds for sorghum midge

Economic thresholds (ETs) are powerful tools for pest management decision-making. ETs describe the number of pests required to cause crop loss (in $ terms) equal to the cost of control—essentially the break-even point. Re-arranged, the ET calculation can provide a prediction of the crop loss likely to occur (for a specific pest density) if no preventative action is taken.

The ET calculation for sorghum, with midge resistance is:

$$\frac{M}{MR} \geq \frac{(C \times W)}{(V \times R \times 1.4)}$$

Where

M = number of midge per metre row
MR = hybrid midge resistance rating
C = treatment cost ($/ha)
W = row width (cm)
V = crop value ($/tonne)
R = insecticide residual life (days)
1.4 = grain yield lost (g) per ovipositing midge without control

The role of residual efficacy in midge management

Interviews with agronomists showed major differences of opinion on how long the useful residual efficacy (R) of SPs was for midge control, with estimates varying from 1-10 days. Because R has such a big influence on the crop loss calculation, it is important to understand how a spray for midge impacts on midge activity.

Residual efficacy only protects the heads that were fully emerged at the time the crop was treated. In a crop where all heads emerged on the same day, the full benefit of the residual would be realised across the crop. In other words, every head would be protected for the residual period. However, this scenario is very rare, and head emergence is more typically staggered (occurring over one to three weeks). This means that even if a crop was sprayed today, any head that emerged after spraying would be susceptible to midge damage.

Despite recent DAF trial work that shows reasonably long residual efficacy of commonly used insecticides for midge control in the laboratory (Figure 1), the practical in-field benefits of residual efficacy are actually quite limited. For this reason, the following scenario uses a conservative period of 3 days' protection from a midge spray.

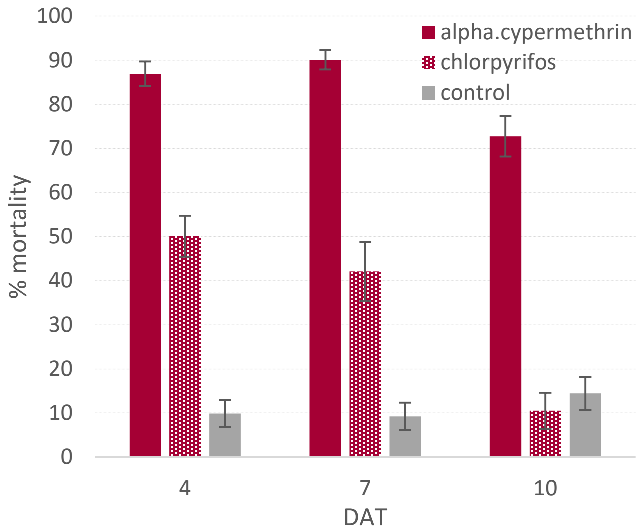

Figure 1. Residual efficacy of alpha cypermethrin (synthetic pyrethroid) and chlorpyrifos (organophosphate) at 4, 7 and 10 days after treatment (DAT) on female sorghum midge exposed to treated spikelets.

Examining the true value of midge resistance

The greatest opportunity lost in sorghum midge management is not taking full advantage of the MR of the variety planted. In the example below, we compare different levels of MR, illustrating the difference in the number of midge that can be tolerated in the higher MR varieties.

Case study assumptions

Unless otherwise stated, the case study uses the following values in the ET calculation:

- farm gate price (V) of $220/tonne for sorghum
- row spacing width (W) of 100 cm
- sorghum midge resistance (MR)
- insecticide residual life (R) of 3 days
- cost of treatment (C) is based on using a SP and estimated at $10/ha.

Net benefits of midge resistance levels

Table 1 demonstrates the net economic benefit or loss of spraying midge for given levels of sorghum MR and midge population densities.

Table 1. Net benefits of midge treatment for given levels of midge population densities and sorghum midge resistance.

Midge (/m row)	Net economic benefit of controlling midge ($/ha)							
	MR1	MR2	MR3	MR4	MR5	MR6	MR7	MR8+
1	-1	-5	-7	-8	-8	-8	-9	-9
2	**8**	-1	-4	-5	-6	-7	-7	-8
3	**18**	4	-1	-3	-4	-5	-6	-7
4	**27**	**8**	2	-1	-3	-4	-5	-5
5	**36**	**13**	5	2	-1	-2	-3	-4
6	**45**	**18**	**8**	4	1	-1	-2	-3
7	**55**	**22**	**12**	**6**	3	1	-1	-2
8	**64**	**27**	**15**	**8**	5	2	1	-1
9	**73**	**32**	**18**	**11**	**7**	4	2	0
10	**82**	**36**	**21**	**13**	**8**	5	3	2

The numbers bolded in Table 1 show when it is economical to treat, assuming that a grower gets at least a cost-benefit ratio of 1:1.5 (>$5/ha net benefit). The reason for setting a higher threshold is that there are other agronomic costs that have not been directly considered in this case study, such as the unintended impacts of midge sprays on natural enemies or other pests. These secondary outcomes can potentially lead to increased treatment costs to control other pests and an increased risk of insecticide resistance for midge and non-targeted pests, such as helicoverpa.

The sorghum industry has greatly benefited from the midge resistance program. At no host plant midge-resistance (MR1) it was worth spraying at any midge density greater than 1 midge/m row, but with varieties of MR6 or greater, even 10 midge/m row can be tolerated.

An interesting relationship in Table 1 is how the net benefits of treatment decrease at a diminishing rate as MR increases. Although there are no longer any commercial lines at MR1, the change in net benefits of treatment between MR1 and MR2 at 9 midge/m row is $41/ha. However, the difference in net benefits between MR7 and MR8+ at this midge density is only $2/ha.

This relative reduction in net benefit as MR increases indicates that developing resistance levels beyond MR8+ is unikely to provide a useful benefit unless midge populations are very high, and in these circumstances SP treatments can still be undertaken. This potentially allows breeding programs to focus on other agronomic production constraints to benefit industry, provided those traits do not cause a reduction in MR levels.

Midge ETs with respect to crop price

The net economic benefits of the case study scenario was based on sorghum farm gate price of $220/t (V) and the level of midge resistance. Table 2 investigates the effect of crop price on midge economic thresholds. As the price of sorghum decreases the ETs increase, and vice versa.

Table 2. Midge economic thresholds (midge/m row) for given crop price and sorghum midge resistance rating.

	Midge/m row economic thresholds (ET)				
MR	$170/t	$195/t	$220/t	$245/t	$270/t
1	1.4	1.2	1.1	1.0	0.9
2	2.8	2.4	2.2	1.9	1.8
3	4.2	3.7	3.2	2.9	2.6
4	5.6	4.9	4.3	3.9	3.5
5	7.0	6.1	5.4	4.9	4.4
6	8.4	7.3	6.5	5.8	5.3
7	9.8	8.5	7.6	6.8	6.2
8+	11.2	9.8	8.7	7.8	7.1

The net benefit of treatment is greatly affected by the level of sorghum midge resistance (MR).

For example, two sorghum crops have 7 midge/m row. One is planted with MR-Buster (MR=4) and the other with the midge resistant equivalent variety Resolute (MR=8+). Under the assumptions of this case study, the net benefit from treating the MR-Buster crop is $6/ha, compared to an economic loss of -$2/ha in the Resolute crop.

MR ratings for some commonly available sorghum hybrids are provided in Table 3. Contact your seed company or reseller for the MR rating of hybrids not listed.

Table 3. Examples of sorghum hybrids and their respective midge resistance ratings.

Hybrid	MR rating	Seed company
Resolute	8+	Pacific Seeds
A66	7	Pioneer
Halifax	7	Pacific Seeds
HGS-114	6	Barenbrug
MR-Taurus	6	Pacific Seeds
85G33	6	Pioneer
A75	6	Pioneer
SW11668	6	S&W Seeds
Brazen	5	Radicle Seeds
Sentinel IG	5	Pacific Seeds
HGS747	5	Barenbrug
SW12472	5	S&W Seeds
MR-Bazley	4	Pacific Seeds
Liberty	4	Barenbrug
MR-Buster	4	Pacific Seeds
Agitator	4	Radicle Seeds
Cracka	3	Barenbrug

Midge damage to sorghum head.

Considerations

1. If the crop is in areas with large volumes of Johnson grass there may be increased midge pressure, especially in wetter years.
2. More even flowering through plant density and variety selection can improve the duration of insecticide efficacy.
3. The MR rating tends to be more important for crops planted later in the season.
4. The ET does not consider the cost of spraying out natural enemies of midge and helicoverpa, therefore the cost-benefit ratio of spraying needs to be >1:1.5.

References

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