Management Changes for Bollgard®II and New Technology

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Introduction

As with the introduction of any new technology, when it occurs rapidly, there is likely to be mixed views from users unless it is self-evident that its advantages out-weigh its disadvantages. The rapid change being experienced by the Australian cotton industry at present with the transition from Ingard to Bollgard II technology is a good example.

Another background paper in these proceedings (Kelly *et al, Industry Perceptions on Management Issues Associated with Bollgard® II*) reports on a range of pre-2003/04 season perceptions on the management of Bollgard II. A number of the issues raised in this feedback from growers and consultants are discussed in this paper and the associated paper by Dr Greg Constable. In many cases growers and consultants see the introduction of Bollgard II as a means of offering new opportunities to achieve improved yields and increased profits, however, for others there are concerns with having to rapidly adopt this new technology, some of these have a basis in fact, others are possibly based on limited experience with Bollgard II and some others appear to be based more on perception than fact.

In terms of perceived differences between managing Bollgard II and conventional cotton, the issues most mentioned in over 70 pre-2003/04 season semi-structured interviews (reported by Kelly *et al)* were: sucking pests/secondary pests, water, nutrition, early cut-out, plant development, yield and quality performance, planting date and plant population. Information gaps in managing Bollgard II were identified in the areas of: plant growth (high fruit retention in Bollgard II), nutrition, irrigation management, efficacy performance under adverse and high pest pressure conditions, insect management particularly monitoring and secondary pest management, and the new Bollgard II varieties.

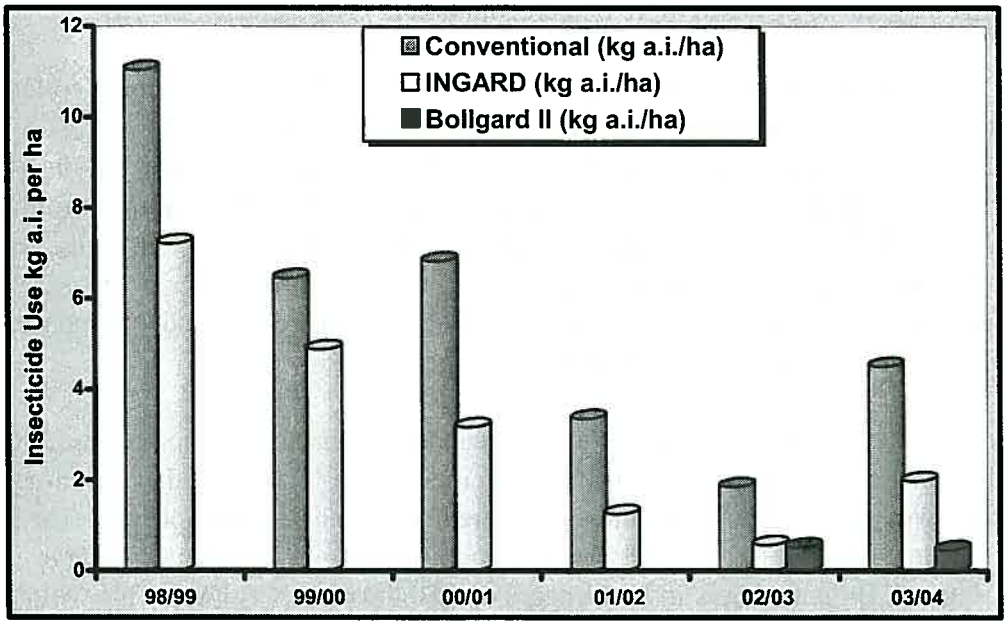
It is interesting to note that the growers and consultants interviewed prior to the 2003/04 season seldom made mention of resistance management in Bollgard II either in terms of a perceived area where management would be different or as an information gap. The rapid transition from Ingard to Bollgard II has been brought about by the need to preserve insect susceptibility to the Bt gene that is in both Ingard and Bollgard II (Cry1Ac). This will ensure the starting susceptibility to the two genes in Bollgard II is maximised and hence the longevity of the technology also has the greatest potential of being maximised. Recent research on monitoring and understanding resistance to both of these Bt genes shows clearly that some of the assumptions underlying our current Bollgard II Resistance Management Plan may not be completely reliable. As a result, in the Bollgard II era, effective resistance management will be paramount if the industry is to gain the maximum advantage and longevity from it.

Insect Management in Conventional, Ingard and Bollgard II Cotton

In considering what management changes might be needed for Bollgard II, it is instructive to look back on some of the experience, challenges and changes in management that have occurred with Ingard over the last 6 to 8 seasons. With Ingard not registered in 2004/05, the last two seasons, particularly 2003/04, have provided the only opportunities to directly compare widespread commercial performance of conventional, Ingard and Bollgard II.

Figure 1 compares the industry average quantities of insecticide and miticide active ingredient applied per hectare on conventional and Ingard crops over the last six seasons with estimates for Bollgard II included for the last two. This measure of Ingard performance shows that it has steadily improved each season but has still shown the same trends relative to conventional cotton. Compared to 2002/03, the quantities of chemical active ingredient applied to both Ingard and conventional cotton increased in 2003/04 (due to the high *Helicoverpa punctigera* infestations experienced in 2003/04), but quantities of chemical applied to Bollgard II remained at very low levels. This indicates that Bollgard II can be expected to perform well under high *Helicoverpa* pressure.

Figure 1. Industry average insecticide plus miticide use on conventional, Ingard and Bollgard II cotton expressed in kg active ingredient per ha.



Source: Estimated from CCA Market Audit Survey 2004 data

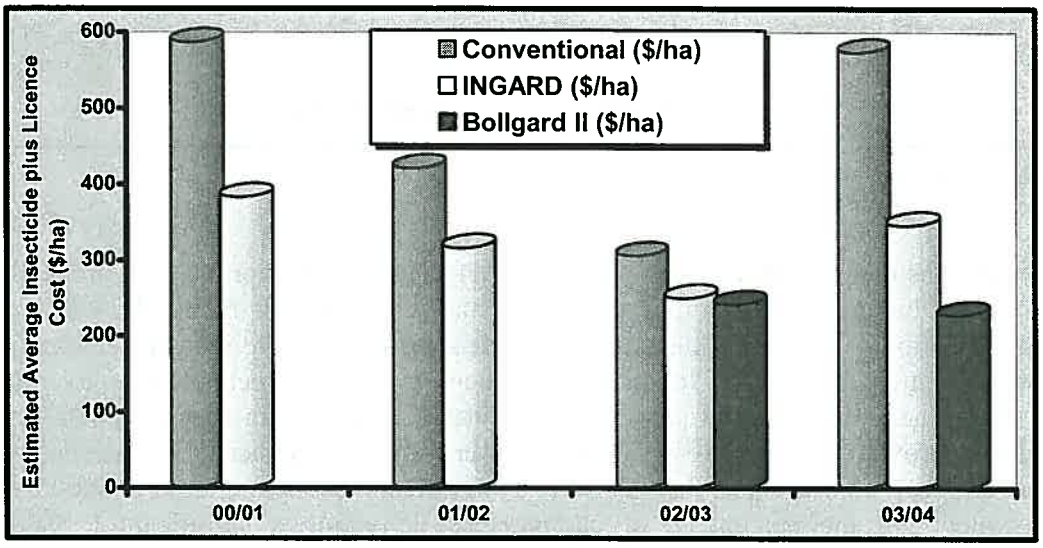
Table 1 shows that the types of insecticides used on conventional, Ingard and Bollgard II crops in 2003/04 also differ. Products used for *Helicoverpa* control dominate in conventional cotton, while in Ingard there is more of a mixture of *Helicoverpa* and sucking pest products. In contrast, Bollgard II crops were treated almost exclusively for sucking pests.

Table 1. The Five Most Commonly Used Insecticides or Miticides in Conventional, Ingard and Bollgard II Cotton in 2003/04 (based on the estimated number of applications – CCA Market Audit 2004)

Conventional	Ingard	Bollgard II
Amitraz	Dimethoate	Dimethoate
Affirm	Abamectin	Regent
Steward	Chlorpyrifos	Pegasus
Tracer	Indoxacarb	Abamectin
Chlorpyrifos	Regent	Endosulfan

Another measure of relative performance is shown in Figure 2 which compares estimated costs of controlling insects and mites in conventional, Ingard and Bollgard II. Both Ingard and Bollgard II costs include licence fees. Note that, for comparative purposes, the Bollgard II licence fee used in both seasons was the same as the Ingard fee applying in 2003/04.

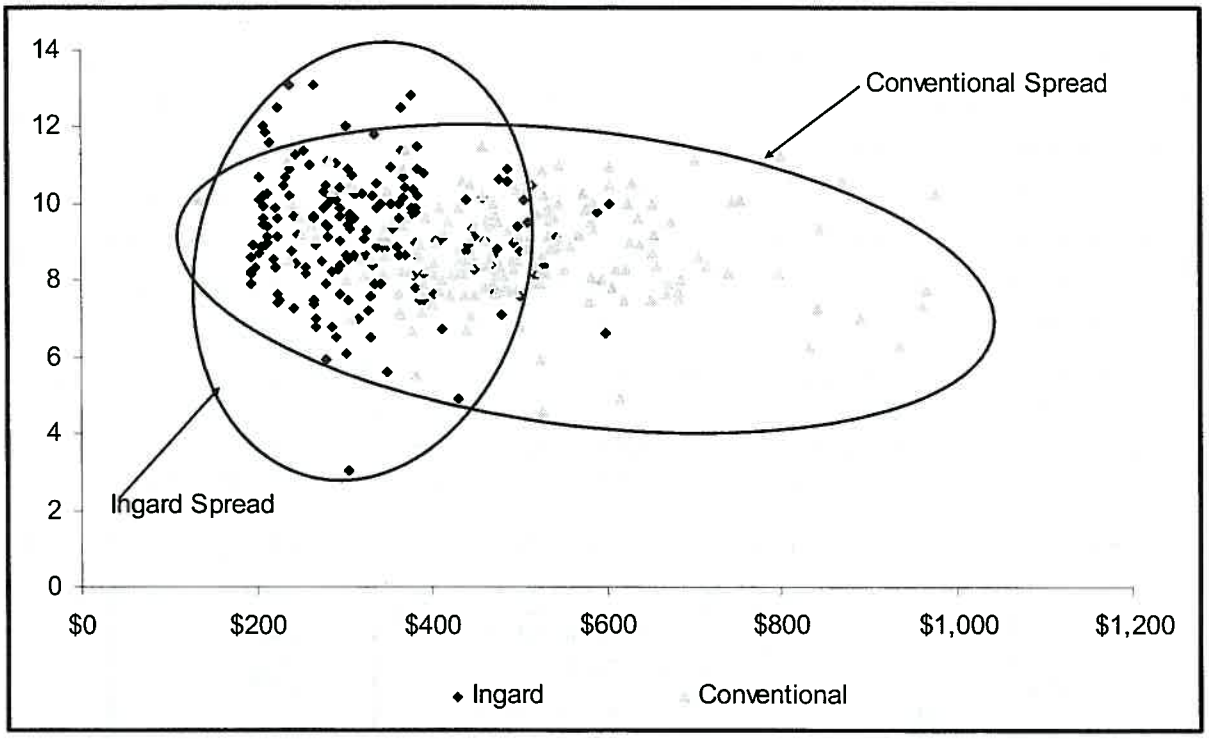
Figure 2. Estimated insect and mite control costs for Conventional, Ingard and Bollgard II 2000 - 2004



Source: Estimates from CCA Market Audit Survey 2004 data (Note: Bollgard 03/04 price used for 02/03)

Figure 3 shows the relative performance of Ingard and conventional cotton measured in 2001/02 by Doyle *et al* 2002b by plotting the spread of yield and pest control costs from a sample of "paired" crops (i.e. data points are from pairs of Ingard and conventional crops from a large number of farms). Clearly the spread of costs from the Ingard crops is far less than for conventional crops. Drought conditions have prevented gathering a large enough set of samples to provide comparisons between conventional cotton and Bollgard II, however, it is anticipated the level of performance from Bollgard II will be no worse than for Ingard.

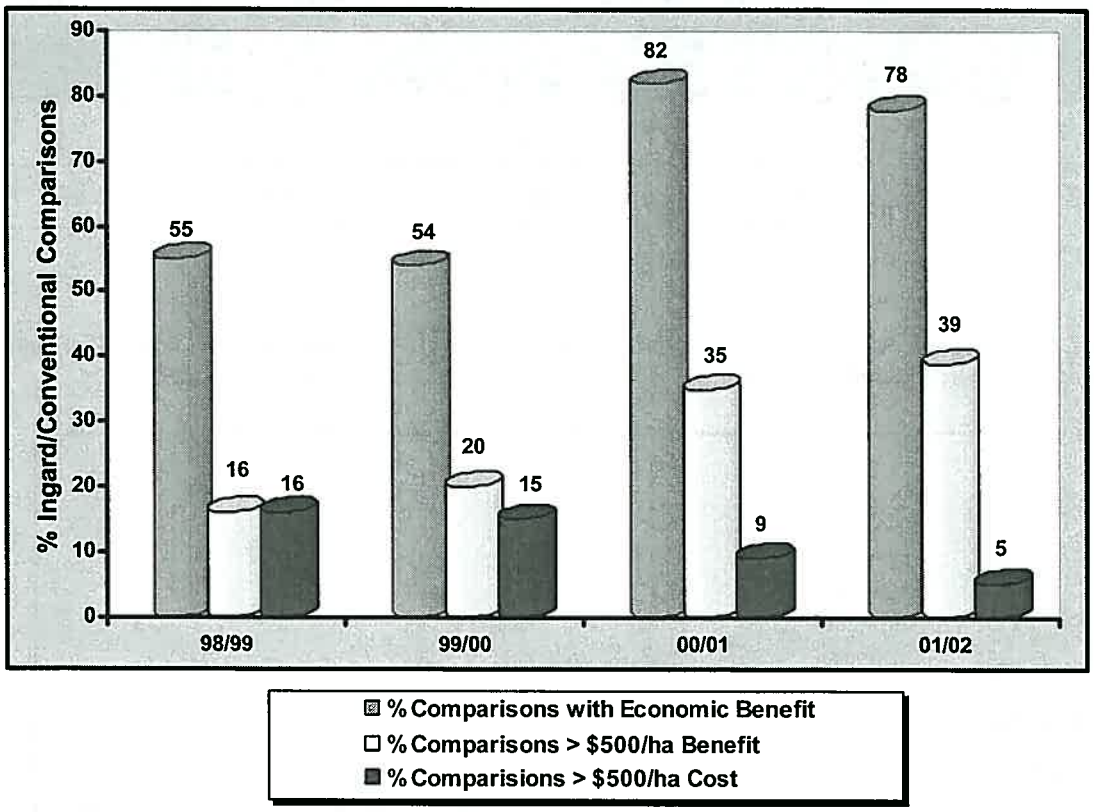
Figure 3. A comparison of yield vs pest control costs for Ingard and conventional cotton, 2001/02*.



*Source Doyle *et al, 2002b.*

Over the 8 seasons that Ingard has been grown its performance has improved. Figure 4 shows evidence for this based on a series of annual performance evaluations funded by CRDC and conducted by Cotton Consultants Australia (CCA). It shows that in the seasons leading up to 2000/01 only a little over half of Ingard crops, when compared directly with conventional crops off the same farm, returned an economic benefit. However, in seasons 2000/01 and 2001/02 this improved to around 80%. Similarly, over the period depicted, the percentage of Ingard/conventional comparisons that showed a significant economic cost (>$500/ha) to Ingard declined and the percentage of comparisons delivering a significant (>$500/ha) economic benefit to Ingard increased. These results suggest that average economic performance in Ingard has improved and the negative impact of variable performance, which was so evident in the first three to four years of Ingard production, has declined.

Figure 4. Evidence of the improved overall and reduced negative variability in economic performance of Ingard cotton over 4 seasons*



Sources: *The Performance of Ingard Cotton in Australia* – Reports from 1998/99, 1999/2000, 2000/01 and 2001/02

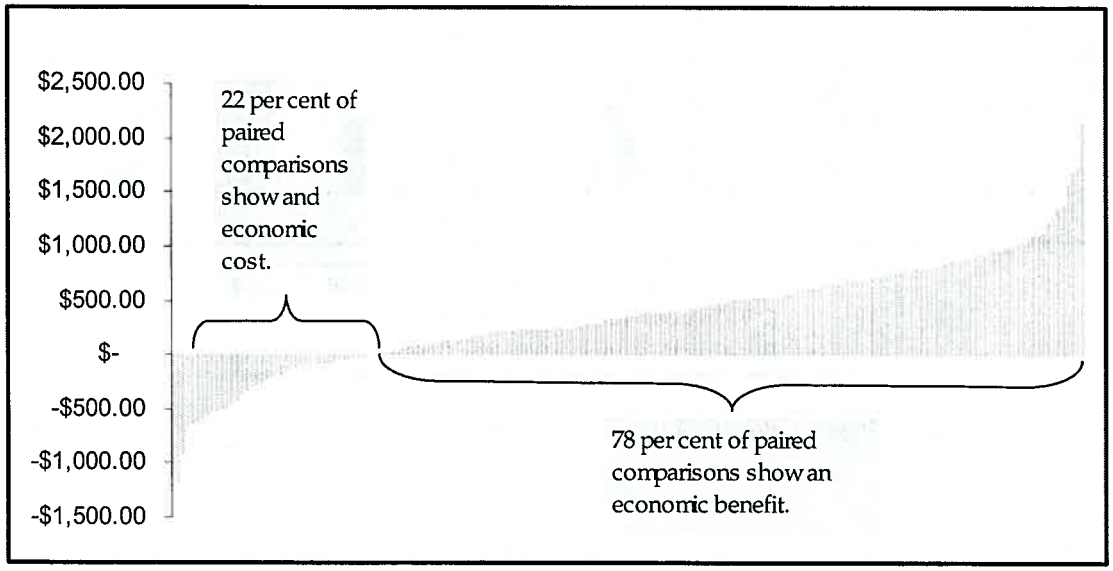
Despite these improvements, Figure 5 demonstrates that the variability in economic performance of Ingard can still be quite extreme even in a season where the average economic performance is considered excellent. Much of this variability is due to the fact that the quantity and therefore the efficacy of the Cry1Ac protein produced in Ingard plants declines as the season progresses. This has made management of Ingard a very difficult issue for growers and consultants, but the fact that there have been so many gains made in pest management in both Ingard and conventional cotton over the last five years shows how effectively the people in the Australian cotton industry can address challenges.

Table 2 provides another indication of how the performance of Ingard has improved over time. It summarises the answers of consultants surveyed, in two of the annual Ingard performance evaluations (Pyke, 1999 and Doyle *et al* 2002b), to a question why their grower clients grew Ingard. The positive changes in attitude and confidence with Ingard are substantial.

Table 2. Reasons for growing INGARD - percentage of responses.

Season	No. of responses	Environmental benefits	Insect management/ IPM Benefits	Reduced spraying benefits	Economic and yield benefits
1998/99	125	80%	10%	10%	0
2001/02	173	27%	28%	17%	28%

Figure 5. Variability of economic performance of Ingard in 2001/02 shown as the results of all paired comparisons with conventional cotton*.



*Source Doyle *et al, 2002b.*

How will Bollgard Efficacy and Performance Compare?

At present, with Bollgard II, we lack the wealth of information that is available on the efficacy and performance of Ingard. Despite this, early results with Bollgard II suggest that it has superior efficacy to Ingard particularly from mid to late season. The fact that Bollgard II crops performed well under quite high mid season *H. punctigera* pressure in 2003/04 suggests that it will be a more robust product than Ingard from this point of view.

The five most applied insecticides and miticides shown in Table 1 for Bollgard II in 2003/04 clearly indicate that sucking pests, particularly mirids, but also aphids and mites will be the main target pests for additional chemical control in these crops. In comparison to the products

used in Ingard, some of which were targeted at *Helicoverpa*, these early results confirm that Bollgard II can be expected to perform better against these target pests.

Monitoring Bollgard II for Pests and Maintaining IPM Systems

With improved performance against *Helicoverpa*, many growers and consultants are asking: will Bollgard II require a similar level of monitoring for pests as does conventional and Ingard cotton? Given that Bollgard II will be sprayed much less than conventional cotton and also less than Ingard has been sprayed to date, we can expect there to be changes in the timing and intensity of infestations of a number of secondary pests. Mirids in particular are likely to exploit the reduced early season spraying in Bollgard II and, therefore, will become one of the key pests in terms of maintaining good IPM systems as well as the potential to flare secondary pests such as mites, aphids and Silverleaf whitefly. There are few soft options available for mirid control and, because some of the cheaper broad-spectrum sprays for mirids can flare other pests by eliminating beneficials, spray decisions for mirids will need to be made very carefully. This suggests that Bollgard II crops will still need to be monitored thoroughly with aspects such as mirid damage, fruit retention and boll piercing damage assessments all becoming much more important requirements.

Therefore, until we gain more experience with Bollgard II, it would be prudent to continue with our current crop monitoring standards of 2 to 3 crop inspections for pests each week while the crop is actively growing.

Managing Resistance to Bollgard II – Important Management "Changes"

This heading might seem an unusual one for many growers and consultants as the current Resistance Management Plan for Bollgard II is an extension of the key elements used for resistance management to Ingard. So what changes in resistance management might be necessary for Bollgard II?

Resistance management for Ingard has been based on the preventative concept of keeping the frequency of potential resistance genes at a very low level in the *H. armigera* population. Consequently, practices such as planting on farm refuge crops, in which the pests are not exposed to Bt, and pupae busting under Bt cotton are vital in resistance management. They have proven successful in the case of Ingard because, even though at least two genes conferring resistance to the Cry1Ac Bt protein are known to exist in the field, gene frequencies for these have been maintained below the current level of detection.

Improving the effectiveness of these key resistance management practices will be essential with Bollgard II. Herein lays the need for some possible changes in management for the future. With Bollgard II, the potential to remove the 30% cap imposed on single gene Ingard is to be exploited in 2004/05 with growers able to plant up to 95% Bt cotton provided they plant a refuge crop equivalent to 10% unsprayed cotton (in this example a 5% pigeon pea refuge would be the option). The removal of the cap is based on the expectation that two-gene

Bollgard II provides a more robust technology to which it will be far more difficult for the target pests to develop resistance. Recent research is starting to indicate that some of the assumptions that underpin this expectation are not as solid as we would like to see. The consequence of this is that, unless every grower applies the elements of the Resistance Management Plan effectively, the anticipated long-term efficacy of Bollgard II against *H. armigera* will not be sustained.

Some areas of concern with Bollgard II include:

- At least one resistance gene to the second or new gene in Bollgard II (i.e. the gene producing the Cry2Ab protein) has been detected even before Bollgard II has been widely grown
- This gene is present in the *H. armigera* population in quite high (detectable) frequency
- It may not be completely recessive, meaning that some of the heterozygotes (i.e. insects carrying one resistance gene) may survive exposure to Bollgard II late season.
- Efficacy of the first Bt gene (i.e the gene producing the Cry1Ac protein) in Bollgard II will continue to show a decline through the season as in currently does with Ingard. This means that, at the end of the season, the second Bt gene will be the only one acting fully.

On the other hand, because some of these shortcomings have been identified in advance and because there is no solid evidence for pest cross-resistance to the two "Bollgard" genes from the field, we have the opportunity to improve our Bollgard II resistance management in the near future to address these new challenges.

Some of the management changes that will be needed will revolve around ensuring refuges are made more effective. If we can't achieve this, then we could be faced with a difficult future choice of reimposing a planting cap or accepting that the efficacy of Bollgard II on *H. armigera* could decline within, say, five years. However, we have reason to be optimistic as we have new tools such as the *Helicoverpa* attractant, Magnet™, which we may be able to exploit to manipulate *H. armigera* populations (gene flow) in our refuges and in Bollgard II.

Conclusions

In general terms our experience in managing Ingard has probably paved the way for Bollgard II more effectively than many may currently realise. Many challenges still lay ahead with this amazing new technology. However, if, as they have always done, Australian cotton growers continue to embrace their challenges as new opportunities, the introduction of Bollgard II will represent another milestone in the further success of the Australian cotton industry.

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