The exceptional yields of 2004–05: What went right?

By James Quinn

The 2004–05 season saw yields well above expectation in all cotton growing regions. Hopefully this is not a one off occurrence, and given similar environmental conditions, these high yields will be equalled if not improved upon in the future. This article aims to highlight factors which enabled growers to achieve such exceptional results.

Farm averages above 10 bales per hectare (four bales per acre) were quite common, and some properties had averages above 12.5 bales per hectare (five bales per acre). This was achieved with the help of exceptional climatic and environmental conditions, the selection of some high yielding varieties and timely management in irrigation and nutrition.

The difference between the higher yielding crops in both conventional and Bollgard II cotton was the ability of the higher yielding crops to retain greater numbers of fruit. Fruiting sites produced between the crops was similar but more of the fruit set was kept in the higher yielding crops.

One of the high yielding crops in 2004–05.

ENVIRONMENTAL ASPECTS OF HIGH YIELD

Climate

The climatic conditions of the 2004-05 season in the post Christmas period were ideal for growing cotton and are largely responsible for the high yields achieved — as highlighted in June–July issue of *The Australian Cottongrower*.

Up until mid December, above average rainfall and resultant floods were experienced in many areas. This flooding did cause some growth setbacks, due to inundation of fields for periods of up to 72 hours.

In the worst cases, this resulted in some plant death, but in most situations it caused fruit losses — primarily the shedding of squares and small bolls. But the long finish to the season enabled these early fruit losses to be more than compensated for.

A benefit that did come from this December rain was the refilling of farm storages and the conversion from what could have been a low water year in most districts to one in which crops were able to be fully watered.

Conversely, the latter half of the season had below average to non existent rainfall (Figure 1). Little rain also means no cloud and no cloud means more sunshine. Clear skies and the outlook of no rain in the future gave growers three luxuries:

- Irrigation scheduling became a lot easier and crop requirements were met. Waterlogging was limited to irrigation events as rainfall did not interfere with the program.
- Those who had full water were able to take advantage of the great finish to the summer, and to finish crops to the top of the plant.
- It afforded them the patience to wait for crops to be completely ready to pick, ensuring a very clean pick and dry modules. Very white, clean cotton in the 11-1 and 21-1 colour ranges has been commonplace.

Milder than average daytime temperatures were experienced throughout last season. There were close to the average numbers of cold shock days and some days where temperatures exceeded 35°C, but the highlight was the lack of the 40°C plus temperatures often experienced during January and February.

These extreme conditions not only play

FIGURE 1: Monthly summer rainfall totals for Wee Waa, 2004–05

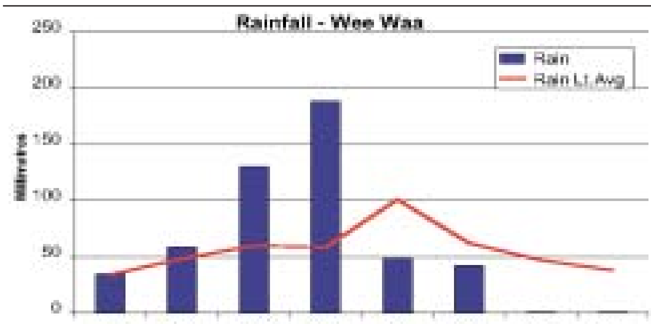

FIGURE 2: December to March radiation figures for cotton districts, 2005

havoc with staff, but shorten irrigation intervals and put high levels of unwanted stress on a demanding crop during boll fill. This was less evident last season. For example, in Moree, maximum daytime temperatures did not exceed 40°C during the entire summer.

Another key indicator of how exceptional the 2004–05 season was for cotton growing was in the above average radiation figures observed in all districts. Almost every day from January onwards was cloudless, and this combined with the milder temperatures to allow the plants to produce to their potential.

Some of the more southern growing districts recorded higher radiation figures than the Bourke average for the December–April period (Figure 2). Of all the growing regions, Bourke has the highest average accumulated solar radiation for this period.

Gunnedah, which normally has comparatively low levels of solar radiation, had radiation levels in 2004–05 greater than the long term Moree average. In all growing regions, this characteristic provided ideal conditions for boll filling and gave a longer than average season.

Long fallow

Up to 70 per cent of the 2004–05 cotton crop was grown on fallow fields — many enforced since the 2001 summer. Not surprisingly, most of the highest yielding crops came from fallow fields. A recent survey conducted by CSD of growers who grew Sicot 71BR in the 2004–05 season indicated that crops after a fallow achieved an average 10 per cent higher yield than crops following cotton, cereal and legume rotations (Figure 3).

Similarly, yield data from the 41 large scale replicated variety trials where Sicot 71BR was grown indicates an 11 per cent higher yield in those trials planted on fallow compared to other rotations.

The impact a long fallow has on the crop and the subsequent excellent yields has been largely underestimated, mainly because the benefits are often difficult to quantify. Benefits include:

- Improvements in soil structure as a result of the soil's inherent swelling and drying cycles, repairing profiles of fields under long term permanent bed systems. This allows the plant's root system an unhindered ability to explore throughout the soil profile.
- High levels of nitrogen mineralisation. The amount of mineralised nitrogen available in these fields is highly significant, with one six bale per acre crop only receiving 90 kg per hectare of nitrogen fertiliser.
- Allowing many crops to be planted on rain moisture, resulting in significant water savings when compared to back-to-back fields requiring up to two megalitres per hectare of water to refill profiles. Approximately 40 per cent of crops grown last season were established on rain moisture.

Varietal choice

A lot has been said about the performance of Sicot 71 and Sicot 71BR last season with high yields achieved with these two varieties across all regions. A recent survey conducted by CSD showed that Sicot 71BR exceeded all other comparison varieties grown under similar management practices by an average of nine per cent — in some cases it was 22 per cent better than the comparison.

Of 76 Sicot 71BR commercial crops surveyed, 80 per cent yielded higher than four bales per acre, 23 per cent yielded more than five bales per acre and one per cent achieved six bales per acre or more.

The 2004-05 season also showed the enormous benefits of Bollgard II technology. Although it will be classed as a moderate insect year, early insect pressure (particularly *H. punctigera*) was very high in most regions. Yet the retention in Bollgard II crops remained high with early fruit counts giving an indication of things to come with yield. Two thirds of the industry was planted to cotton seed with Bollgard II technology, taking the pressure off a little and freeing up resources to control insects in conventional cotton in a timely manner.

Insects

As mentioned, Helicoverpa pressure in the early season was high — but the majority of these were *H. punctigera*. Although destructive if not controlled, they were relatively easy to manage. Insecticides that were applied generally worked well, although in some cases it took many applications.

After December, Helicoverpa pressure fell dramatically with minimal egg lays and control was needed less frequently. Many conventional crops had eight heliothis insecticide sprays before Christmas and only four afterwards.

This lack of intense insect pressure in the latter half of the season enabled conventional varieties to produce and retain a lot of fruit. Often combined with near perfect growing conditions, this allowed conventional crops to more than compensate for early season tipping and fruit loss. This was highlighted in the defoliation date difference between the Bollgard II crops and those conventional crops of up to two weeks.

What is becoming more evident is the influx of green vegetable bugs and other sucking pests into crops, especially in Bollgard II, late season. High numbers and quick re-infestation time means that this pest will need close monitoring in the future.

Crop factors in relation to high yield

The CSD Extension and Development team has followed up the performance of many varieties by examining different segments of the plant's fruiting structure to assess subtle differences in yield and quality.

The process

The process involved the segmented

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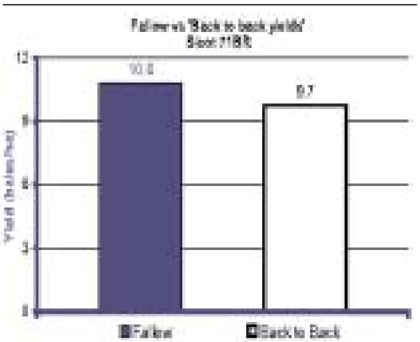
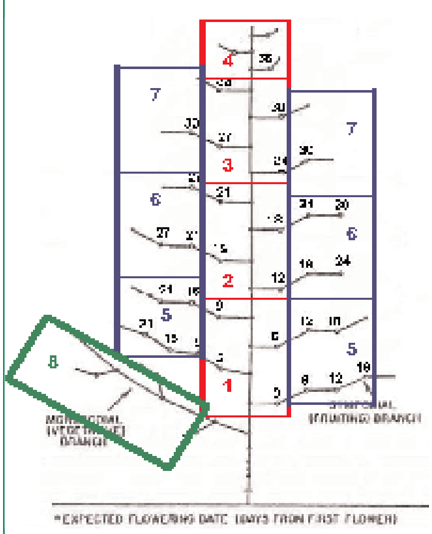
FIGURE 3: Commercial yields of Sicot 71BR from fallow (average of 48 crops) and back to back (average of 28 crops) fields



(Source: CSD Sicot 71BR Survey)

FIGURE 4: Location of fruit from each plant segment



Adapted from Oosterhuis (1990)

◁ 21...HIGH YIELDS

picking of 30 crops where bolls from a number of metres of row were divided into eight segments.

1. Main stem fruiting nodes 1–4, 1st position fruit;
2. Main stem fruiting nodes 5–8, 1st position fruit;
3. Main stem fruiting nodes 9–12, 1st position fruit;
4. Main stem fruiting nodes 13 and higher, 1st position fruit;
5. Main stem fruiting nodes 1–4, 2nd and 3rd position fruit;
6. Main stem fruiting nodes 5–8, 2nd and 3rd position fruit;
7. Main stem fruiting nodes 9 and higher, 2nd and 3rd position fruit; and,
8. Fruit on vegetative branches or laterals.

See Figure 4.

The boll numbers were recorded from each segment and lint was retained and ginned with a 10 saw experimental gin, providing yield, turnout and boll weight. Lint samples were then HVI classed for micronaire, staple length and strength. In a number of crops, seed numbers were counted and weighed and then analysed for concentrations of nitrogen, phosphorous and potassium.

This study generated a lot of data allowing comparisons between varieties, technologies (Bollgard II and conventional), and most importantly provided information about some of the exceptional yielding crops from the 2004–05 season. Much of this data was presented during the CSD Information Tour.

TABLE 1: Sensitivity analysis between boll number and weight, yields shown as bales per acre

		Grams of lint/boll				
		1.6	1.8	2.0	2.2	2.4
Bolls/Metre	80	2.3	2.6	2.9	3.1	3.4
	100	2.9	3.2	3.6	3.9	4.3
	120	3.4	3.9	4.3	4.7	5.1
	140	4.0	4.5	5.0	5.5	6.0
	160	4.6	5.1	5.7	6.3	6.8
	170	4.9	5.5	6.1	6.7	7.3

The 'boll box' used for segmented picking.

What constitutes yield?

An age old question is what makes up yield? A simplified way to break up the components of yield is through the equation:

Yield = Fruiting sites x Retention x Boll size

Fruiting sites equates to the total number of squares produced by the plant. Retention is the proportion of those squares which make it through to a pickable boll. The combination of these two numbers gives bolls per metre.

Boll size refers to the amount of lint per boll. This can vary dramatically, between varieties, fields, regions and even within fruiting positions on the plant.

The importance of both boll number (combination of fruiting sites and retention) and boll weight is great (Table 1). For example, yield from a crop with 120 bolls per metre could vary from 3.4 to 5.1 bales per acre, depending on boll weight. Examples of this were seen last season with small crops with modest boll counts achieving yields of over 10 bales per hectare (four bales per acre).

What influences boll weight?

Factors that will influence final boll weight occur throughout the season. The number of ovules (potential seeds) per boll is set at squaring, by physiological and genetic factors, and even nutrition. The number of these ovules that become seeds is determined during flowering — this being established by the level of pollination and fertilisation and greatly affected by climate. It is not well understood when the number of fibres per boll is determined, but the weight of these fibres is mostly determined after flowering as these fibres are elongating (first 15–25 days after flowering) and thickening (final part of boll fill period, 25–60 days).

The segmented picking work illustrated some interesting trends in these variables. While higher numbers of seeds per boll resulted in higher boll weights (Figure 5), the amount of lint per seed had a greater impact on final boll weight (Figure 6).

So if it is possible to achieve high numbers of seeds per boll through good climatic conditions and crop management, there is a greater chance of achieving a good boll weight. But there is still potential to compensate for low seed number per boll by increasing lint weight per seed, which is mainly determined late in the season.

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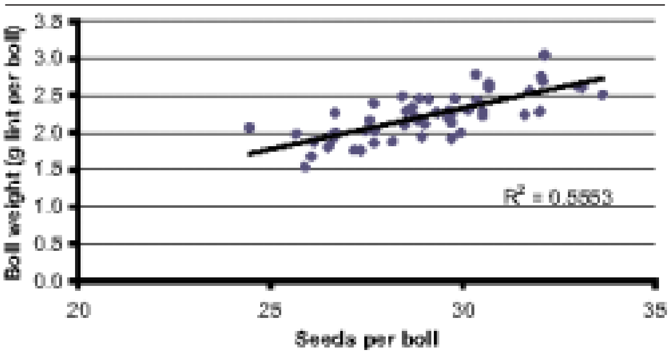
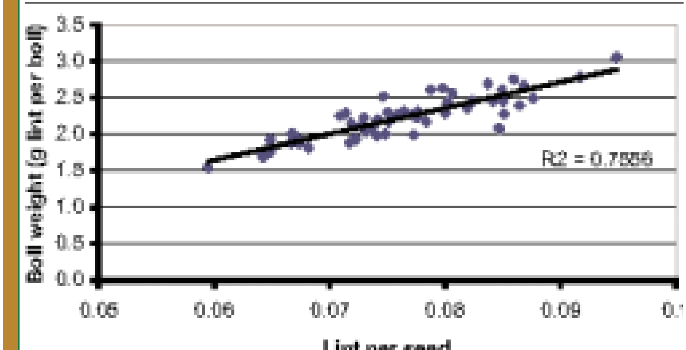
FIGURE 5: Relationship between seeds per boll and boll weight (grams of lint per boll)



Data from all segments in seven crops. Trend indicates more seeds per boll results in higher boll weight.

FIGURE 6: Relationship between the amount of lint per seed (g) and boll weight (grams of lint per boll)



Data from all segments in seven crops. Trend indicates more lint per seed results in higher boll weight

◁ 22...HIGH YIELDS

Comparison between Bollgard II/Roundup Ready and conventional cotton crops

Each season, the CSIRO plant breeding team conducts advanced line trials (ALT) across most regions where many varieties of all technologies are grown within the same field. In three of the ALT sites in 2004–05 (Gwydir, Balonne, Macintyre), segmented picking was conducted on Sicot 71BR and Sicot 71 to determine the differences between conventional and Bollgard II crops.

Analysis of the data showed very similar boll numbers and boll weight (Table 2) but there were striking differences in the plant architecture. The Bollgard II crops were predominately singular in stem due to low levels of early season terminal damage while the conventional crops had multiple stems as a result of the heavy early season Helicoverpa pressure.

As a result of the terminal damage, the conventional crop did produce a lot more fruiting positions (many on vegetative branches), but retained approximately 35 per cent less than the Bollgard II crops. Data on the actual number of fruiting sites was not recorded, but simple maths on the total bolls per metre and the percentage retention shows the conventional variety had approximately 65 per cent more fruiting sites than the Bollgard II crops.

In the main stem dominant Bollgard II crops, 65 per cent of bolls came from main stem first position fruit, while only 35 per cent of the bolls were produced in the same zone in the conventional crops.

This factor has led to the suggestion that there were many instances of conventional crops out-yielding Bollgard II crops in the 2004–05 season. The terminal damage produced a potentially greater number of fruiting sites and the ideal climatic conditions and low Helicoverpa pressure late in the season allowed a high proportion of these to make it through to become large bolls.

Management implications of this are going to be quite varied. The conventional will be slightly later in maturity. Data from the Cotton CRC has shown that conventional crops which incur heavy tipping will be approximately a week later than non tipped plants.

The demand for assimilates to fill late bolls may be higher in these tipped crops and will need to be carefully managed to ensure nutrients and water are maintained till the end of the season.

TABLE 2: Segmented picking data comparing conventional and Bollgard II fields

	Sicot 71	Sicot 71BR	Difference
Fruiting Sites	More	Less	
FP1 Retention	39%	64%	–25%
Bolls/metre	124	129	–5
Boll Weight (g)	2.30	2.21	+4%
Turn Out	42.2%	40.3%	+2%
Yield (b/Ha)	12.6	12.5	+1%

Table 3: Segmented picking data comparing very high and high yielding Sicot 71 crops

	Sicot 71 >5b/ac	Sicot 71 ≈4b/ac	Difference
Fruiting Sites	Similar		
FP1 Retention	48%	31%	+17%
Bolls/metre	167	108	+55%
Boll Weight (g)	2.25	2.32	–3%
Turn Out	41.4%	43.0%	–1.6%
Yield (Hand Pick) (b/ha)	16.5	11.0	+57%
Yield (Actual)(b/ha)	14.0	12.1	+15%

Table 4: Segmented picking data comparing very high and high yielding Sicot 71BR crops

	Sicot 71BR >5b/ac	Sicot 71BR 4b/ac	Difference
Fruiting Sites	Similar		
FP1 Retention	73%	46%	+58%
Bolls/metre	159	111	+43%
Boll Weight (g)	2.16	2.04	+5%
Yield (Hand Pick)(b/ha)	15.1	9.97	+51%
Yield (Actual)(b/ha)	13.4	9.7	+38%

On the other hand, the peak demand of the Bollgard II crops is going to be during the January–February period, due to the higher proportion of first position bolls. Crop nutrition and water have to be carefully managed to ensure development and extra growth and to avoid an early cut out.

Five bales versus four bales — what are the differences?

Segmented picking was carried out in some of the exceptional yielding (12.5+ bales per hectare) commercial crops throughout the industry. To determine where this extra yield came from, they were compared with crops that yielded around 10 bales per hectare. These comparison crops were not from the same property. Comparisons were made across both conventional and Bollgard II crops.

Conventional

Two conventional crops of Sicot 71 (Gwydir) which yielded above 12.5 bales per hectare (5.0 bales per acre) and two crops yielding about 10 bales per hectare (4.0 bales per acre — Border Rivers) have been grouped for this comparison.

In this comparison, the higher yielding crops had 55 per cent more fruit per metre (Table 3) than the lower yielding comparisons.

The zone where this difference is most pronounced is the 1st and 2nd positions from node five and higher. The higher yielding crops had 85 bolls per metre in these segments while the lower only had 35 bolls per metre. That is a 50 boll per metre difference, which is half as many bolls again than the lower yielding crops. This accounts for the difference in the final yield.

The higher yielding crops were able to retain and fill a greater proportion of these bolls through to harvest. Through good nutrition and irrigation management, and favourable climatic conditions, these crops were able to continue producing fruit, whereas the lower yielding crops did not produce harvestable bolls past node 12.

There was a large difference in the hand picked yields. Obviously the hand picking was carried out in some of the higher yielding sections of the fields. Achieving a spot yield of 16.5 bales per hectare (6.6 bales per acre) is an impressive result, even if hand picked. But it is an indication of the ability of Sicot 71 to produce high yields, and sets a target for yields in the years to come.

When analysing this data, the question of insect pressure and number of insecticides has often been raised. Interestingly, when examining the number of bolls on vegetative branches and the first four fruiting nodes, the crops are very similar, which may suggest that insects were not a limiting factor and most likely it was the inability of the lower yielding crops to produce and retain fruit on the top nodes.

Sicot 71BR comparison

Three crops of Sicot 71BR (Gwydir, Darling Downs, Macquarie) comprise the above 12.5+ bales per hectare crops and three Sicot 71BR crops (Border Rivers, and two from Central Queensland) have been grouped for the 10+ bales per hectare crops.

Similar to the conventional, the difference in yield between the high yielding (13.4 bales per hectare average) and the lower yielding (9.7 bales per hectare) crops appears to be directly related to boll numbers (43 per cent), brought about by a 58 per cent greater first position retention (Table 4).

The zone in the crop where this difference is most obvious is fruiting nodes 1–12. The higher yielding crops had 85 bolls per metre in this section whereas the lower yielding crops only had 45 bolls per metre. Interestingly, boll numbers at the top of the plant and on vegetative branches were similar between the comparison crops.

Bollgard crops have a different fruiting habit.

An interesting point in these comparisons is that boll weight is greater in the higher yielding crops (five per cent). In the conventional comparison, the boll weight of the lower yielding crops is slightly higher (by three per cent).

In both the conventional and Bollgard II comparisons, the higher yielding crops had a greater capacity to hold on to fruit, especially in the middle and near the top fruiting branches of the plant.

These are fruit that are often at the stage of small bolls (and hence very prone to shed) at the time when the demand of the crop is the greatest. At this peak boll fill stage, when a limiting factor for carbohydrate production is reached, boll filling is the main priority. The first thing a plant will sacrifice is vegetative growth and young bolls. Reducing vegetative growth can reduced the total fruiting sites, and losing young bolls reduces retention.

The challenge for growers is have a crop producing enough carbohydrates to both sustain boll filling and to retain bolls later in the crop. The limiting factor for this occurring is not always easy to identify. Sometimes it will be climatic, such as overcast weather, waterlogging, or very high night temperatures. Sometimes it may be related to water or nutrition — a deficiency or excess of either. Or there may be soil structural constraints (such as compaction).