Managing For High Yields and Quality

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In recent seasons, as the yields being achieved by Australian growers have skyrocketed, the Cotton Seed Distributors (CSD) team has made a dedicated effort to gather information about these high yielding crops; what these crops look like and what was taken to get them there.

This is a work in progress; our investigations to date have definitely raised more questions than answers.

Our information comes from a range of sources, primarily our large-scale replicated variety trial program in which we've conducted 368 trials across the industry in the past seven years since the commercial release of varieties with Bollgard II. These trials give us the opportunity to test our new varieties with some of the best growers in the industry. Our segmented picking program is used to collect very detailed information about crops, by dividing up bolls by their location on the plant. This information gives us a good understanding of what section of the plant is contributing most to yield. In the past six seasons our team has conducted segmented picking at 316 sites across the industry. That equates to over 1km of row hand picked and 2 ½ thousand samples taken.

Whilst managing for fibre quality is in the title of this presentation, most of the focus is on yield. However, if you're producing high yields, generally you're also producing good quality; particularly the parameters of fibre length and staple strength.

What is yield?

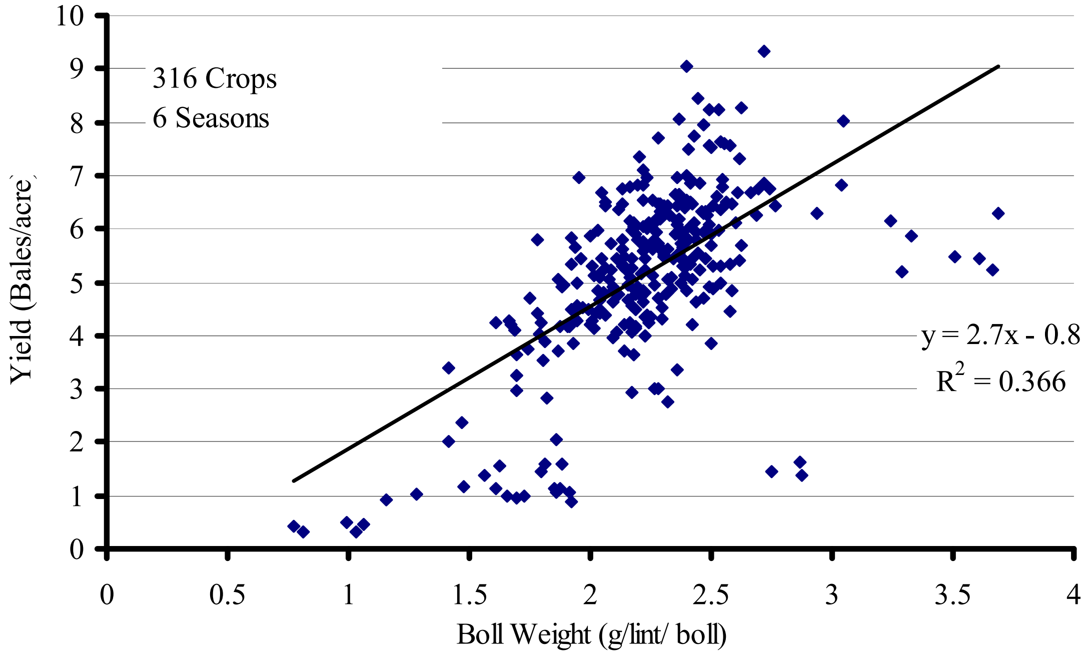
Yield is a function of the number of bolls that are harvested multiplied by the weight of each of those bolls. The number of bolls is determined by the number of fruiting sites set and the proportion of these that make it through to a harvestable boll; i.e. the plants retention.

Boll Weight

When the amount of lint per boll was compared with the yield from the 316 crops that have been segmented picked over six seasons, it was found most bolls range from 1½ to 2½ grams of lint per boll and also that heavier bolls are generally associated with bigger yields (Figure 1).

As with the earlier comment about fibre quality, generally if you've got a crop healthy enough to produce a lot of bolls, they will be heavy also. Also influencing this data is that the higher yielding varieties also tend to be those we have seen in the very high yielding crops.

Figure 1. The influence of boll weight (g/lint per boll) on yield from 316 crops across the Australian industry in the past six seasons.



Boll weight is a function of the number of seeds per boll and the amount of cotton lint on each of these seeds. The number of seeds is determined by the number of ovules set and the number of these that go on to become seeds. The lint per seed is determined by the number of fibres and how much each fibre weighs.

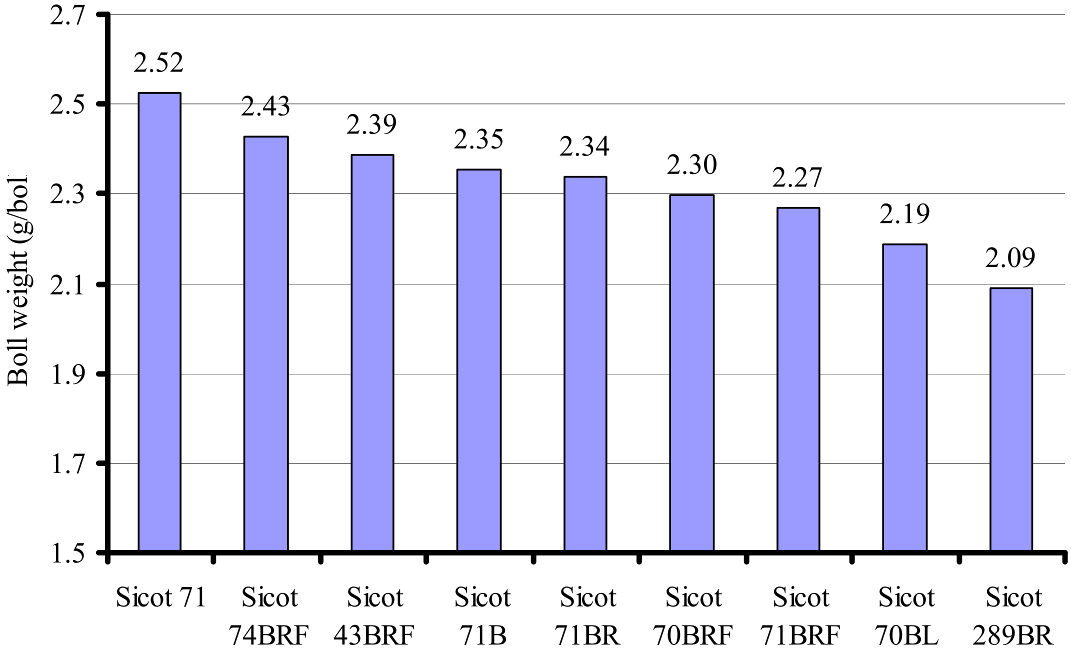
Some Influences on boll weight

In our studies it has been difficult to find many common denominators in regards to boll weight but region and variety do stand out.

Some varieties inherently have heavier bolls. Across the varieties we've investigated in sufficient numbers over the past six years there is a 20% difference in boll weight between the variety with the heaviest and that with the lightest bolls (Figure 2). This difference is not unexpected because all the individual factors of boll weight mentioned previously are genetically based.

The study indicated some regions inherently produce lighter bolls. The segmented picking database included the same varieties grown in the same seasons across the regions and whilst most regions were similar, the Lachlan/ Murrumbidgee was a stand out – producing bolls about 10% lighter than those in other areas. None of the information from our database could give an indication to the cause of this.

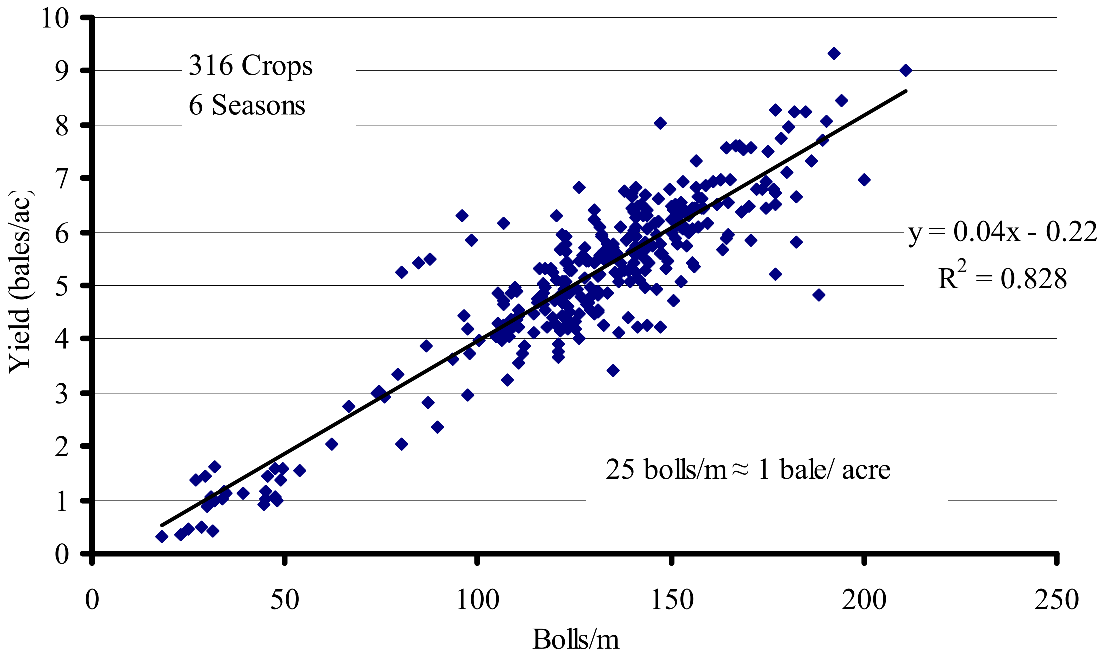
Figure 2. Average boll weight (g/lint per boll) for all varieties included in paired comparisons in CSD's segmented picking program.



Boll Number

Boll number is a function of the amount of fruit set multiplied by the proportion of these that make it through to harvest; i.e. the plant's retention. Our data strongly indicates that more bolls per metre means higher yields – in fact increasing the boll count by 25 bolls per metre will improve yield by one bale per acre.

Figure 3. The influence of boll number (bolls/m) on yield from 316 crops across the Australian industry in the past six seasons.



Analysing the big yields

One of the most interesting aspects of the segmented picking work is analysing what's different between those extremely high yielding crops – those above 7 bales per acre and those more average crops in the 3 ½ to 4 ½ bales per acre range. In our 316 crop sample we were fortunate enough to have about 20 sites where the plots we harvested yielded over 7 bales per acre.

To keep this comparison consistent we only used varieties in the Sicot 71 group, which incidentally make up a large portion of the sample anyway, and we've only used solid planted irrigated crops. The selection of higher and lower yielding crops also comes from a range of regions.

Hand picked plot yields are always going to be higher than commercial yields. Every boll that we harvest goes into a sealed paper bag so there are no picker or transport losses. We gin our samples through an experimental 20-saw gin which produces turnouts 2-3% percent higher than commercial gins. Nevertheless, they are still very high yielding crops.

Big yielding Bollgard II® vs big yielding conventional

In the 20 crops in our >7 bale/acre group, we had a selection of conventional and Bollgard II crops. From boll considerations, a 7 bale per acre conventional crop looked similar to a 7 bale/ acre Bollgard II crop - both had about 175 bolls per metre and boll weights of around 2½ grams of lint per boll. The Bollgard II had slightly higher first position retention but the conventional crops made up for this by retaining more second and third position fruit (figure 4).

Big yielding conventional vs low yielding conventional

In this comparison, boll weights were similar – both around 2½ grams of lint per boll so the big difference was boll number – there was about 70 bolls per metre more in the big yielding crops (figure 4)..

This difference stems from a combination of factors. The first position fruit retention in the higher yielding crops was around 50% while the lower yielding crops were around 20%. The higher yielding crops set more fruit at the top of the plant and held onto more fruit in the outer positions.

Big yielding Bollgard II® vs low yielding Bollgard II®

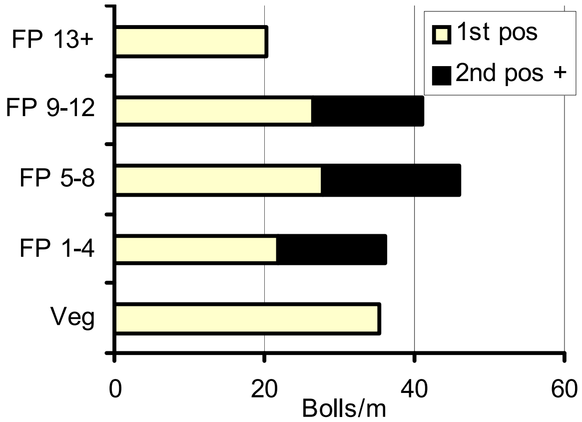
In the lower yielding group of these crops we had a couple of different scenarios. About 15% of these had very low retention, hence low boll numbers and looked similar to the lower yielding conventional crops (not shown in figure 4). By far the most common scenario in the lower yielding Bollgard II was what appears in the bottom-left graph in figure 4.

Again we saw a large difference in bolls per metre – over 50 more in the high yielding crops but what's particularly interesting is where on the plant this difference was. The first position fruit retention of both was reasonably similar at about 60% - in fact the number of early set fruit in both was around 60 bolls per metre. The difference is these big yielding crops put on and held more fruit later in the season – about 115 bolls per metre – almost double that of the lower yielding crops.

In this scenario the boll weights were also about 15% lower in the lower yielding group, mainly due to significantly lighter bolls in the later set positions.

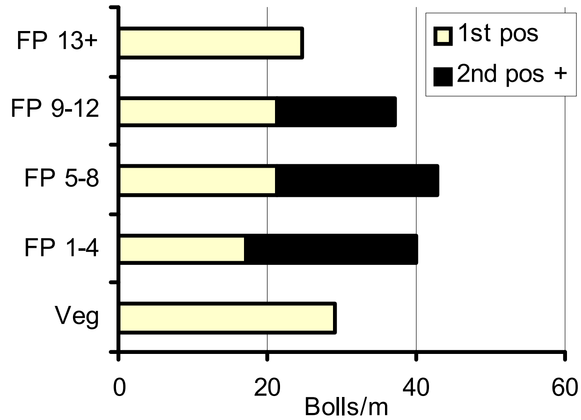
Figure 4. Bolls/m from each plant segment from high yielding (>7 bales per acre) and lower yielding (3.5 – 4.5 bale per acre) Bollgard II and conventional crops. Note FP = the fruiting branch on the main stem, 1st pos = first position fruit, 2nd + pos = second and greater position fruit, veg = fruit on vegetative branches.

Bollgard II® - >7 bales per acre



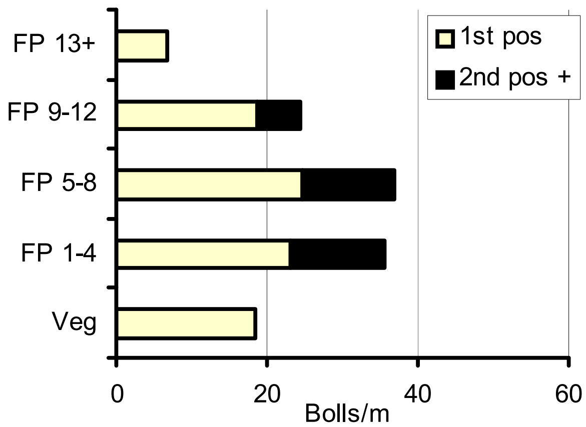
Bolls/m = 179 bolls/m **Boll weight** = 2.4 g/boll
Mainstem retention = 64%

Conventional - >7 bales per acre



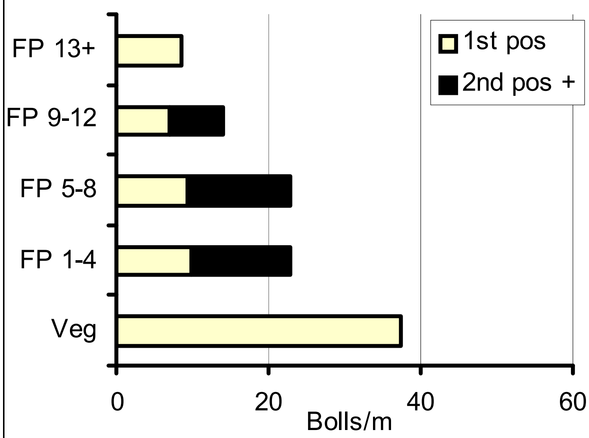
Bolls/m = 174 bolls/m **Boll weight** = 2.5 g/boll
Mainstem retention = 50%

Bollgard II® - 3.5 – 4.5 bales per acre



Bolls/m = 122 bolls/m **Boll weight** = 2.1 g/boll
Mainstem retention = 55%

Conventional - 3.5 – 4.5 bales per acre



Bolls/m = 106 bolls/m **Boll weight** = 2.4 g/boll
Mainstem retention = 22%

The big yielders simply grew well and flowered for longer – and consequently were able to convert this into extra yield.

Theoretically, at about 50 percent retention, these higher yielding crops would need to effectively flower for about eight weeks to achieve 170 bolls/m – about 2 weeks longer than it would take to achieve 120 bolls/m. In this case, active flowering means the plant is strong enough to be able to continue to produce and hold new flowers whilst having enough resources to fill and produce large bolls throughout the plant. This should not be confused with trying to restart a crop that has cut-out.

Most of these big yielding Bollgard II and conventional crops were in the 21-24 node range – no bigger than that. The difference is that they held on to more bolls at the top of the plant and in the outer positions.

The happy plant

For all this to happen, quite simply you need a happy plant – one that has access to the water and nutrition when it needs it from a soil that is sufficiently aerated. The plant has access to sufficient heat and sunlight, and is not constrained by diseases or pests. Any one of these could be the crop's limiting factor.

When a crop is firing on all cylinders, it's getting all the resources it needs and they're getting directed into the yield components. This means a very efficient plant, particularly in its use of nutrients and water.

Nutrition

Constable and Bange (2006) discussed the nutrient requirements of these large yielding crops and the in-crop efficiencies achieved. To capture these efficiencies we've assumed a 7 bale per acre crop will remove 10 kg N per bale while the lower yielding crop will remove 12 kg of N per bale (Table 1). A 7 bale per acre crop may need to take up 290 kg/ha N during the season – of which 175 will be exported as lint and seed.

The relationship with potassium and phosphorus is more linear. A 7 bale crops may uptake 350 kg of potassium and export 140 kg and it may remove 45kg of phosphorus.

The obvious issue when considering these quantities is replacing them and the critical importance of soil and plant testing.

Table 1. Comparing the nutrient requirements of a 7 bale/ acre and 4 bale/ acre crop. Based on Constable and Bange (2006).

			4 bales/ acre	7 bales/acre
Nitrogen	Uptake (kg/ha)	12kgN per bale	**198**	*347*
		10kgN per bale	*165*	**290**
	Removal (kg/ha)	12kgN per bale	**120**	*208*
		10kgN per bale	*100*	**173**
Potassium	Uptake (kg/ha)		**200**	**350**
	Removal (kg/ha)		**80**	**140**
Phosphorus	Removal (kg/ha)		**26**	**45**

Water

Again, using the data from Constable and Bange (2006), using the efficiencies we achieved by growing our happy plant we compare a 7 bale per acre that delivers 2 bales per megalitre and a 4 bale crop at 1.25 bales per megalitre. A 7 bale per acre crop may push about 9 megalitres per hectare through the plant over the season. Assuming there is 1 megalitre stored in the soil at the start of the season and 2 megalitres comes from effective in-crop rainfall, it means you've got to supply that crop with almost 6 megalitres of water. At an irrigation efficiency of 75% it means the irrigator may need to pump about 7½ megalitres per hectare.

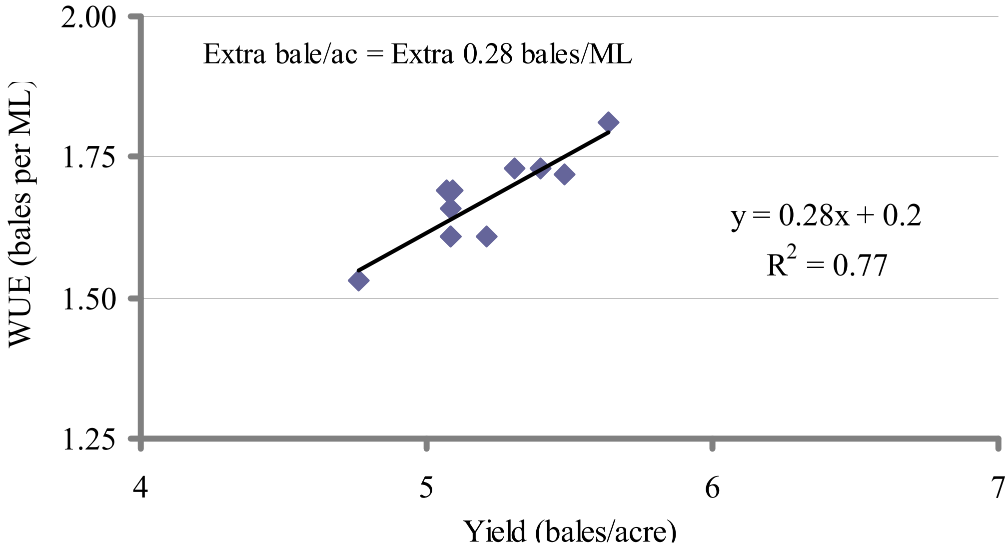
Table 2. Comparing the water requirements (ML/ha) of a 7 bale/ acre and 4 bale/ acre crop. Based on Constable and Bange (2006).

		4 bales/ acre	7 bales/acre
Water Used	1.25 bales/ ML	**7.9**	*13.9*
	2.0 bales/ ML	*5.0*	**8.7**
Irrigation required	1.25 bales/ ML	**4.9**	*10.9*
1ML in soil, 2ML rain	2.0 bales/ ML	*2.0*	**5.7**
Water pumped	1.25 bales/ ML	**6.6**	*14.5*
75% Irrigation Efficiency	2.0 bales/ ML	*2.7*	**7.6**

To illustrate this further, CSD's James Quinn measured the total amount of water used by plants in 11 Sicot 71BRF crops over the past two seasons and derived a water use efficiency figure in bales per megalitre. He then compared this to the actual yield of the crop (Figure 5).

For every extra bale per acre in yield, we increased the water use efficiency of that crop by about ¼ of a bale per megalitre – reinforcing the fact that a happy crop is an efficient crop. It also verifies the assumptions used in Table 2, suggesting a 4 bale/acre would produce 1.26 bales/ML and a 7 bale/acre crop 2.16 bales/ML.

Figure 5. Comparing total crop water use efficiency (WUE) with the yield (bales/ acre). Demonstrating a high yielding crop is a more efficient user of water.



Making it happen

Achieving happy plants and those outstanding yields take a combination of good luck and good management. Unfortunately, there's no set recipe that's right for every crop, every season.

When we looked at some common denominators for the high yielding crops– the most standout was fallow versus back-to-back. As an example, when we looked at every trial that had Sicot 71BR included – that's 144 crops over five seasons, it clearly showed a 13% yield improvement from fallow fields compared to back-to-back. That is over $550 per hectare more.

This comparison is roughly the same for every variety and shows a similar trend to that coming from work done by Brian Hearn in the 1970s which showed a 12% improvement, Greg Constable in the 1980s which showed an 8% improvement and Nilantha Hulugalle last decade which showed a 19% improvement.

There are some factors which a grower has little control over. Extreme weather events at any time of the season can set a crop back enough that will prevent it from ever producing very high yields. We've seen instance of a wet start where the plant develops a very shallow and lazy root system that is not capable of sustaining a good boll load later in the season. Wet weather in the middle of the season can cause fruit shedding and at the end of the season – boll rots. Diseases like Fusarium and Verticillium wilts block the plants vascular system so it can't feed the bolls what they need.

There are some cotton growing soils which are simply not able to meet the demands for nutrients and water a high yielding crop requires. This includes soils that are hard setting, shallow, very sandy, sodic at depth, heavily compacted and also flat fields that experience multiple water logging events most seasons. In more years than not, these soils will not deliver very high yields and simply adding more inputs such as fertiliser will not change this.

Crop monitoring is essential – if you can't do it yourself, employ a good person to do it for you. If you know what's going on - you've got an opportunity to manage it. Precision agriculture and remote sensing techniques have taken crop monitoring to a whole new level, but even these work best when used in conjunction with a good, experienced set of eyes.

The best thing you can do is get the basics right, monitor heavily and make sure the crop has what it needs and do it on time. Aim to make sure that the crops limiting factor is not something you have control over such as water timing, nutrition and insect management.

Acknowledgements

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Reference:

Constable G, and Bange M (2006), What is cotton's sustainable yield potential? Australian Cotton Grower, Volume 26, pp 6 – 10.