

Cotton Vision 2030

Greg Constable, Australia.

ICAC Researcher of the Year 2015



Dr. Constable is former Principal Research Scientist, CSIRO Food and Agriculture, Australia. He served as the Director at CSIRO, Australia. He is considered as the leader of cotton research in Australia and the world. In 2003, the influential Australian business magazine the *Bulletin*, named Dr. Constable 'Australia's smartest scientist'. Some of Dr. Constable's other awards include: CSIRO Chairman's Medal in 2011; Outstanding Research Award in Cotton Physiology at the US Beltwide Cotton Conferences in 2008; ATSE Clunies Ross Award in 2006;

Australian Cotton Growers Research Association Researcher of the year in 2006; Australian Government Prize for Rural innovation in 2005; CSIRO Chairman's Medal in 2003; Centenary Medal for services to plant production and processing in 2001; and the Australian Cotton Growers Research Association Researcher of the Year in 1984. In 2001, Dr. Constable was elected a Fellow of the Australian Academy of Technological Sciences and Engineering for his cotton research.

Three Big Challenges for the Cotton Sector in the Next Decade

1. Competition with synthetic fibres is a challenge for cotton in terms of price, demand, reputation and marketing. Continued promotion of cotton's advantages is necessary, particularly among urban populations. Further gradual improvement in fibre quality also is important to attract buyers in the spinning industry.
2. Water (and land) availability are critical issues in many cotton production systems, due to drought and/or competition with urban needs. This is particularly difficult due to the rapid increase in urban population and decrease in rural population in many countries. World Bank data shows that cotton producing areas in India, Francophile Africa and China have more than a 40% rural population; USA has 18% and Australia, Brazil and Argentina have 14% or less. Mechanisation is one large difference between those groups. High water use efficiency is an important target with crop agronomy.
3. Crop protection from diseases, weeds and insect pests. Integrated Disease Management (IDM) aims to utilise several methods, one of which is breeding cultivars that confer resistance. Crop rotation can reduce disease incidence as well. Integrated Weed Management (IWM) relies on a system where weeds are controlled by a range of methods, rather than reliance on herbicides alone. There are many

instances of continued use of the same herbicide leading to the weed developing resistance. Crop rotation is also a strong component of weed management. Integrated Pest Management (IPM) also requires a range of control measures and as cotton is attractive to many insect pests, cotton entomology is strong in cotton literature. Transgenic insect and weed traits have required a stack of up to three different genes each for insect and weed traits to combat resistance (covered below).

There are always challenges for agricultural industries and cotton has had its share over many years, with issues such as labour, water requirements and pesticide use/contamination. One general challenge is to raise yields in some of the low-yielding production systems. Across the globe there is a very wide range, from 350 to 2500 kg lint/ha, in commercial yields. Francophile Africa is one example of low yield and if the solution were easy, there would have been improvements by now. A concerted effort is required and it must involve socio-economic issues as well as the development of economically productive cropping systems.

Novel Production Technologies that Can Break Yield Barriers

We have estimated the theoretical yield of cotton to be around 5,050 kg lint/ha (Constable and Bange, 2015). That figure is unlikely to be achieved in large scale commercial practice

because it is rare to have perfect conditions throughout the season. However, the extremes of commercial yields across the globe are considerably different: from <400 kg lint/ha to >2500 kg lint/ha. The constraints to production also vary. Liu *et al* (2013) published data from a 30-year study comparing new locally bred Australian cultivars with older standards. The data involved multiple sites each season, covering a range of environments; it was found that there is a strong interaction between Genotype (G), Environment (E) and Management (M). Yield gain for new cultivars from 1995 to 2009 was 18.3 kg lint/ha/year. Recent cultivars also had increased stability across environments. Overall yield gain was attributed to genetics (G) (48%), management (M) (28%) and GxM (24%). The magnitude of GxM differed across production environments (GxExM). The lesson from this study was that modern management was necessary to achieve the best performance from new cultivars. Interaction and compounding between stresses is important in determining yield: Occasional stress during the season can reduce yield more than expected. For example, one day of moisture stress can reduce yields by as much as 15 kg/ha. With three one-day stresses at different times in the season, the yield loss is 65 kg/ha — much more than 3x15 kg/ha. Thus, in rainfed systems with low rainfall, yield can be very low.

The concept of Integrated Crop Management (ICM) highlights the need to ensure all necessary aspects are covered. IPM, IDM and IWM have been covered above, but two other important elements of production are Integrated Soil Management (ISM) and Integrated Quality Management (IQM). ISM ensures that soil health and the practices of soil and seedbed preparation, fertiliser rates and application are all addressed months before sowing the cotton crop. Fallow, crop rotation and appropriate tillage are essential elements of ISM. IQM focusses on ensuring the delivery of the best fibre quality. This will include defoliation timing (if necessary) and harvest to ensure clean and mature fibre all the way through ginning (the grower and ginner need to understand each other's constraints). ICM is not necessarily novel — but the integration of practices is vital.

Promising Advances in the Science of Plant Breeding, Genetics, Genomics and Transgenics

A recent development is the production of high-quality cotton reference genomes (for *G. hirsutum* and *G. barbadense*). That has opened many new options for genetics, functional genomics and mutant gene identification in cotton. Much of that is still used strictly for academic applications but a possible game changer is the rapid reduction in the cost of genome sequencing; there are new protocols that might reduce the price of sequencing to US\$100. This would enable sequencing individual plants in a breeding program, for example, and the ability to apply genomic selection to real breeding problems. Whether it will be better than traditional phenotypic selection is yet to be proven, but it should be used to add value. The development of automation and robots to sample the DNA of thousands of individual seeds speeds up genotyping.

Transgenic cotton with insect and herbicide resistance has been used commercially for 25 years. The value of Bt cotton, for example, depends on the severity of Lepidopterous pests. In Australia, once two and three Bt gene stacks were available, there was good control of *Helicoverpa* sp., the most damaging pest. The number of insecticide sprays was reduced by 90%. There had been a very aggressive IRM protocol established when it was first released in 1996. There is less value in herbicide-resistant traits in Australia so the use of residual herbicides has declined, providing significant environmental benefits. Other desirable targets such as stress tolerance, yield enhancement and others, tend not to have worked because the interactions between genes and pathways are not well understood to engineer them. Many possible traits have patents held by large companies.

How Can Cotton Combat Climate Change?

Climate change (especially warming) and climate variability (especially rainfall) are major global issues that cotton farmers need to deal with. The management options are:

- avoid the problem by changing sowing time or moving to another location,
- tolerate the conditions through breeding for heat tolerance and water use efficiency/water stress tolerance, or
- apply enhanced agronomy systems.

Uneconomic systems should cease. Production systems with reduced greenhouse gas emissions are expected by the general public.

Role of Electronics, Communication Technologies, Models and Apps

With internet and handheld devices, it is possible to have comprehensive apps for many aspects of managing cotton crops. The accurate identification of weeds, pests and diseases, and weather forecasts are possible. Models can be used to optimise irrigation scheduling, fertiliser requirements and yield.

Advice to Young Cotton Scientists: How to Gear Up for the Challenges of 2030

Research into different aspects of cotton production; breeding and processing are very interesting and rewarding. Young scientists need to learn, and perhaps specialise, but it is critical for them to understand the system at a level above and below their chosen area of specialisation. A breeder, for example, should have knowledge of molecular and genomic tools and also of the chosen target agronomy production system. This ensures an appreciation of research gaps and collaboration with other scientists throughout the research spectrum.

References

- Liu *et al* (2013) *Field Crop Res.* **148**, 49-60.
 Constable and Bange (2015) *Field Crop Res.* **186**, 98-106.