Measuring the maturity of unopened cotton bolls

By Robert Long[1], Cheryl McCarthy[2], Mike Bange[1]

AT A GLANCE…

The boll cutting technique allows cotton crop managers to gauge the maturity of cotton bolls. The aim of this work was to assess the feasibility of using near infrared (NIR) portable technology as a non-destructive rapid replacement for boll maturity determination. In a study using a Felix F-750 Produce Quality Meter, NIR spectra (702-1100nm) of bolls that were both immature and mature were successfully calibrated with the instrument using partial least squares regression.

Validation of the model with an independent population correctly identified the maturity of the bolls with greater than 90 per cent accuracy. This technology may assist in guiding decisions around harvest to optimise fibre quality and yield. Future research is working towards developing more precise algorithms to further categorise the maturity of bolls.

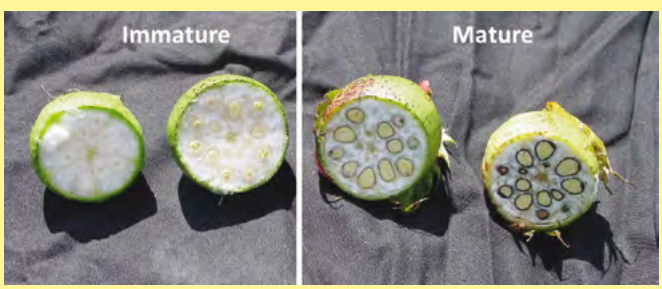
COTTON is a perennial plant grown as an annual crop. To ensure cotton crops are prepared for a single machine harvest, various management strategies incorporating a number of boll and crop maturity measurement methods are employed. One method is the boll cutting technique, as outlined by Mike Bange and co-authors in the 2018 version of FIBREpak, where unopened bolls are cut transversely near the equator. Cut bolls are examined for a number of factors, including examining the colour of the coat and internal tissue of cut seeds (Figure 1).

Dr Robert Long.

Dark seed coat tissue and tan coloured internal seed tissue indicate that bolls are mature enough and ready for boll opening and leaf defoliation (harvest aid) chemistry. While this technique is simple and requires inexpensive tools, it is destructive and time consuming. Considering the biochemical changes occurring in developing bolls, such as to starch, protein and oil levels in the seeds, it is hypothesised that using near infrared (NIR) spectroscopy is an appropriate technology to non-destructively and rapidly determine boll maturity.

The Felix F-750 portable NIR Produce Quality Meter (Felix Instruments, Camas WA) was designed to acquire spectra from whole fruits, and was identified as an appropriate candidate instrument for this work. The aim was to obtain spectra of whole unopened cotton bolls, determine the maturity of these bolls via the boll cutting technique, and then attempt to develop a calibration between NIR spectra and boll maturity reference data.

FIGURE 1: Cotton boll maturity classification via the 'boll cutting technique' or 'knife test'.



Adapted from Bange et al. (2018).

Methods and materials

Unopened cotton bolls of a popular variety were harvested between February and April in 2018 from fields located at the Australian Cotton Research Institute at Narrabri. Bolls harvested

TABLE 1: The number of bolls in each experimental population, and the number of bolls in each population that were designated as either immature or mature via the boll cutting technique

Population	N	Immature	Mature
A	150	96	54
B	70	24	46

FIGURE 2: Cotton boll being held in position for spectral acquisition against the collecting optic of a Felix F-750 Produce Quality Meter – the diameter of the collecting window is 26 mm

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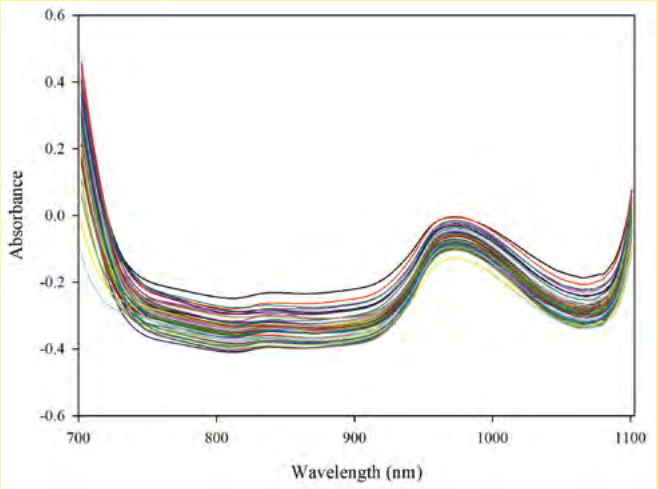
FIGURE 3: Absorbance NIR spectra of a population of cotton bolls



Each coloured trace is a single spectrum acquired from an equatorial position on one cotton boll.

were randomly selected from any position within any given plant, from several tens of randomly selected plants. Two populations were used for experiments. Population 'A' consisted of 150 bolls, and population 'B' consisted of 70 bolls (Table 1).

On any relevant day, bolls were harvested before 11:00am and then set out on a laboratory bench and allowed to equilibrate to ambient air conditions (21 to 25°C) for approximately two hours prior to NIR spectral acquisition. Spectra were then collected from bolls using a Felix F-750 hand held instrument. One lot of spectral information was collected at one equatorial position on each boll (Figure 2). Bolls were then subjected to the boll cutting technique and designated as either mature or immature (Table 1). Partial least squares (PLS) regression using The Unscrambler X version 10.5.1 (CAMO, Oslo) software package, was used to develop a calibration between NIR spectra (Figure 3) and boll maturity data.

FIGURE 4: Using a Felix F-750 Produce Quality Meter to acquire NIR spectral information from a cotton boll in a commercial crop

TABLE 2: Calibration performance statistics for a PLS model developed from population A

Population	R^2cv	RMSECV	I	M	% correct
A	0.64	0.289	6	7	91

The number of bolls that were not designated correctly during cross validation as either I or M are reported. The percentage of bolls that were designated correctly overall by the model are reported.

TABLE 3: Prediction statistics for population B that was validated independently against the PLS model developed using population A

Population	R^2pred	I	M	% correct
B	0.57	4	1	93

The number of bolls that were not designated correctly as either I or M are reported. The percentage of bolls that were designated correctly overall by the model are reported.

Results and discussion

The calibration developed using population A produced reasonable performance statistics (R2cv = 0.64, 91 per cent correct cross validation designation) (Table 2). The calibration was successfully validated. Validation statistics for population B resulted in R2pred = 0.57, correct designation 93 per cent of the time (Table 3). The success of the calibration can most likely be attributed to changes in the biochemistry of developing seeds, and changes in the moisture content of developing fibres might also play a role.

Conclusions

Further work will hope to develop a working calibration for a Felix F-750 and attempt to use the instrument in broader management scenarios (Figure 4). Other portable NIR instruments are likely to be useful also, although the ultimate success of any instrument will depend on whether spectrally meaningful light can penetrate deep enough into boll tissue and be attenuated by relevant molecules. The simultaneous measurement and NIR calibrations to other boll components such as moisture content of fibre and dry matter content of the seeds, might improve non-destructive unopened boll maturity determination. This work also points to a future where such non-invasive equipment might be part of a robotic in-field device, which enables the automatic and constant monitoring of boll and crop maturity.

[1]CSIRO Agriculture and Food
[2]USQ Centre for Agricultural Engineering

For further information on this work please contact Dr Robert Long at the CSIRO: robert.long@csiro.au

Acknowledgements: The Cotton Research and Development Corporation, Ms Ellen Iramu, Ms Jane Caton, Mr Darin Hodgson. Thanks goes to Central Queensland University for the loan of an instrument.

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