



Australian Government

**Cotton Research and
Development Corporation**

FINAL REPORT 2013

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: CMSE1313

Project Title: Revised Leaf Grade Monitor Project (Assessment of IntelliGin Values)

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CRDC Program: Value Chain

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Part 3 – Final Report

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

It is important for ginners to monitor classing and leaf grade in order to maximize grower returns in terms of classing grade, and to reduce fibre damage. The grade from samples drawn during ginning will determine the amount of drying and/or lint cleaning the ginner applies during the ginning of that cotton. Currently most ginners assess classing and leaf grade manually by assessing samples drawn from baled cotton against USDA physical standards. Objective measurement of fibre quality during ginning represents the future of decision-making in ginning. Recently some Australian gins have purchased in-line instrument systems that compare digital images of samples drawn automatically after lint cleaning with images of USDA physical standards. The potential for in-line systems in gins to monitor and control fibre quality has long been recognised.

Both IntelliGin and HVI systems are manufactured by the same company, Uster Technologies of Knoxville TN, USA. The main difference between the two systems lies in their engineering and software; the IntelliGin is adapted to automatically capture fibre samples travelling in the duct (to the battery condenser) via a paddle in the airstream and compress it against the scanning pad for colour, trash and moisture assessment. It is assumed the image analysis software of the IntelliGin system accepts or rejects the form of the captured fibre sample on the basis that a viable scanned image can be obtained for assessment. Although the underlying measurement for the two systems is very similar, the cotton sample density (compression history) and lighting conditions are different. Comparison of results between the two systems may be affected by these differences.

The IntelliGin system is a patented gin process control system owned by Uster Technologies (Knoxville TN) but derived from work by the USDA Stoneville, MS gin laboratory [1-3]. The system makes real time measurements of colour, trash, and moisture and uses this information to control seed cotton and lint cleaner bypass valves. Decision making software algorithms determine optimum process flow based on financial information from a producer loan chart.

The features of IntelliGin were summarized by Ghorashi [2]:

- Real time measurements of fibre colour, trash, and moisture
- Control of dryer's temperature for optimum fibre moisture
- Control of seed and lint cotton by-pass valves

Gins using the IntelliGin system were reported to achieve increase of length (upper quartile length), reduction of nep counts and reduction of short fibre content and deterioration of leaf grade [3-5]. These improvements could also be seen in gins using only one lint cleaner rather than two. However, the reported deterioration in leaf grade due to reduced processing (lint cleaning) resulted in larger, unbroken leaf pieces that were easier to clean in the spinning mill.

Spinning trial results [5] reflected the improvements in fibre property:

- IntelliGin samples contained trash particles with an increased size that proved easier to remove during opening and carding.
- Improved fibre properties at the bale translated to higher quality finished sliver.
- Improved single-end yarn strength from IntelliGin cotton on all spinning systems.

Jones and Williams [4] summarised the value of using gin process monitoring and control. Based on the 1996 gin season at the Servico Gin Company, gin process monitoring and control increased the bale value by \$17.50 / bale (based on 217 kg bale) to the grower. This was accomplished by increasing the amount of gin turnout of 11.3 kg per bale and optimization of moisture levels.

References

- [1] Anthony WS, Byler RK. GIN PROCESS CONTROL: IMPORTANCE TO THE COTTON INDUSTRY. Beltwide Cotton Conference, vol. 1, 1998. p. 703-708.
- [2] Ghorashi HM. APPLICATIONS OF USTER® INTELLIGIN. Proceedings of the Beltwide Cotton Conference, vol. 1, 1998. p. 708-712.
- [3] Yankey JM. IMPROVED FIBER QUALITY FROM GIN. Proceedings of the Beltwide Cotton Conference, vol. 1, 1999. p. 676-678.
- [4] Jones PC, Williams G. THE VALUE OF COTTON GIN PROCESS MONITORING AND CONTROL TO THE TEXTILE INDUSTRY. Proceedings of the Beltwide Cotton Conference, vol. 1, 1997. p. 669-673.
- [5] Mace J. SPINNING INTELLIGIN PROCESSED COTTON. Proceedings of the Beltwide Cotton Conference, vol. 1, Atlanta, GA (2002).

Objectives

2. List the project objectives and the extent to which these have been achieved.

The objective of this project was to compare results from the IntelliGin in-line leaf and colour grade monitor with results on the same attributed bale from a standard HVI (HVI 1000). The comparison is valuable to ginners who are considering purchase of these systems. For growers, the value is in promoting objective assessment of cotton in gins to allow ginners the opportunity to make objective decisions with regards to the extent of drying, cleaning and moisture addition. The comparison provides ginners already using these systems with independent evidence of the systems value and directions for improvement.

This objective has been achieved.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

The location of the IntelliGin system in the gin is shown in Figures 1(a), (b) and (c).

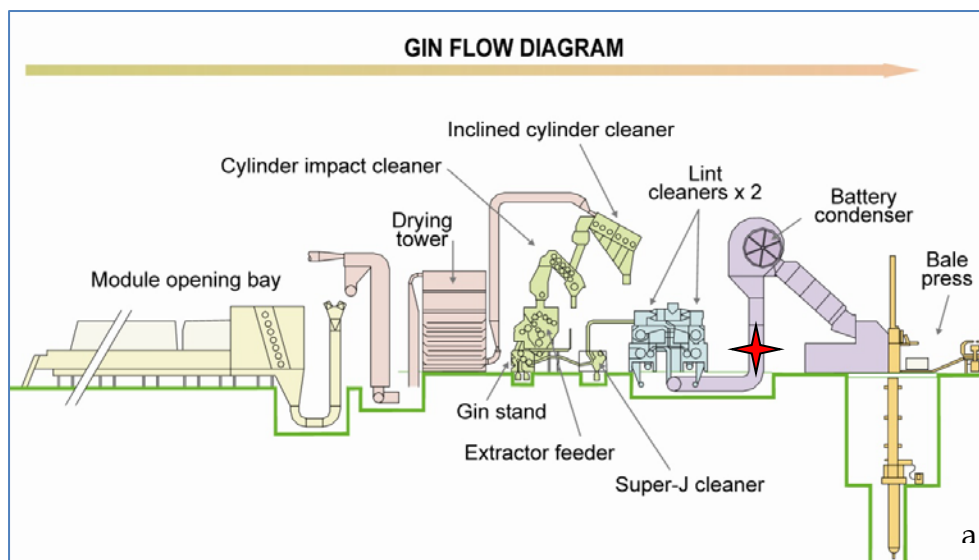


Figure 1(a) – Position of the red star shows the location of IntelliGin system in a gin, and the gins observed in this project. The ducting at this point transports accumulated cotton from 6, 8 or in some cases 10 lint cleaners. A monitor reporting the IntelliGin measurements typically sits in the gin console room (not shown)



Figures 1(b) and 1(c) – Photos show position of IntelliGin system in a cotton gin; arrow in shows direction of air and cotton flow to battery condenser

Datasets used in statistical analysis

The datasets with corresponding HVI and IntelliGin results were supplied from three gins in different growing regions; Warren, Trangie and Narrabri. Each gin/region provided 65-67 sets of data representing about 200 bales (module averaging data is taken every three bales). All data were collected during May 2013. The complete datasets are provided in the Appendix to this report¹.

¹ Appendices are not attached to this CRDC report; a full report with appendices has been sent separately.

Table 1 – Sources of datasets

Region	Bale numbers
Warren	70422227 - 70422426
Trangie	10538351 - 10538549
Narrabri	90705796 - 90705994

Additional samples

An additional batch (bale numbers 70514886 – 70514 950) of data was supplied from the Warren gin and analysed against samples taken manually after the battery condenser but before the bale press. These grab samples were tested using standard HVI procedures and compared with the corresponding, nominal bale results from the IntelliGin and HVI samples from the bale. The aim of this comparison was to check for differences between the two systems based on compression history. For example, the manually drawn samples were not compressed (baled) before HVI measurement. The null hypothesis employed in this comparison was that if manually drawn samples gave the same values as the HVI bale samples then compression history has no effect on the measurement of specimen values.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

Trash / Leaf grade by HVI

Cotton trash content can be evaluated both visually and instrumentally. For the visual evaluation of trash content, seven physical standards are used to determine leaf grades designated 1 to 7. One descriptive standard is used to rate leaf content that is “below grade”.

The instrument used to measure trash content in cotton is the HVI Trashmeter. The Trashmeter scans the surface of the cotton sample, separates trash areas from the lint, and reports the percentage of total trash areas. The HVI Trashmeter provides a rapid trash measurement at a low cost using a video camera at standard conditions. Although the instrumental trash determination and the classer’s leaf grade are not the same, there is a correlation between the two [6].

Correlation between leaf count, area and grade - HVI

Consolidated dataset

The HVI data provides corresponding values of leaf count, leaf area and leaf grade for each bale. This allows us to explore how the two image-based parameters (leaf count C and leaf area A) are related to the machine-assigned HVI leaf grade (LG). The data from all the three regions were consolidated into one, from which multi-parameter and single-parameter regression analyses were conducted. Table 2 is the Excel multi-regression summary of the outputs.

Table 2 – Summary of regression outputs for consolidated the HVI leaf grade dataset

<i>Regression Statistics</i>					
Multiple R	0.751616				
R Square	0.564926				
Adjusted R Square	0.560464				
Standard Error	0.316844				
Observations	198				
<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	2	25.41883	12.70941449	126.5999473	5.7528E-36
Residual	195	19.57612	0.100390362		
Total	197	44.99495			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	
Intercept	0.988099	0.067167	14.7110536	1.90524E-33	
leaf area%	1.052093	0.382227	2.75253207	0.00647191	
leaf count	0.059171	0.005568	10.6270250	4.20975E-21	

The multi-regression equation obtained is

$$LG = 0.9881 + 1.0521 A + 0.0592 C$$

The adjusted $R^2 = 0.5605$, i.e. 56.05% of the variation of the leaf grade around the mean is explained by the leaf count and leaf area. This sounds to be quite low, but we should take into account of the integer nature of leaf grade (i.e. fractional grades are not allowed). The true accuracy is more correctly reflected by the residuals (difference between actually assigned grade and predicted grade). For example, a calculated $LG = 1.6$ would be rounded to grade 2 (residual = 0.4). In other words, only those predictions with residuals greater than

0.5 grade are incorrect predictions. Using this as a criterion, we find that 181 out of 198 bales were predicted correctly, and 17 bales (8.6%) were not predicted correctly.

From the ANOVA table, the F-test statistic is 126.6 with a p-value of 5.75×10^{-36} . This leads to the conclusion that the parameters jointly are very highly significant. However, upon examining the two parameters separately, we find the t-statistic is 2.75 for A ($p = 0.065$, not significant at $p = 0.05$) while the t-statistic is 10.63 for C ($p = 4.2 \times 10^{-21}$, highly significant). The Excel line fit plots for the multi-regression in Figure 2 also show a highly linear line up of data points for the leaf count and a wider dispersion of data points for leaf area.

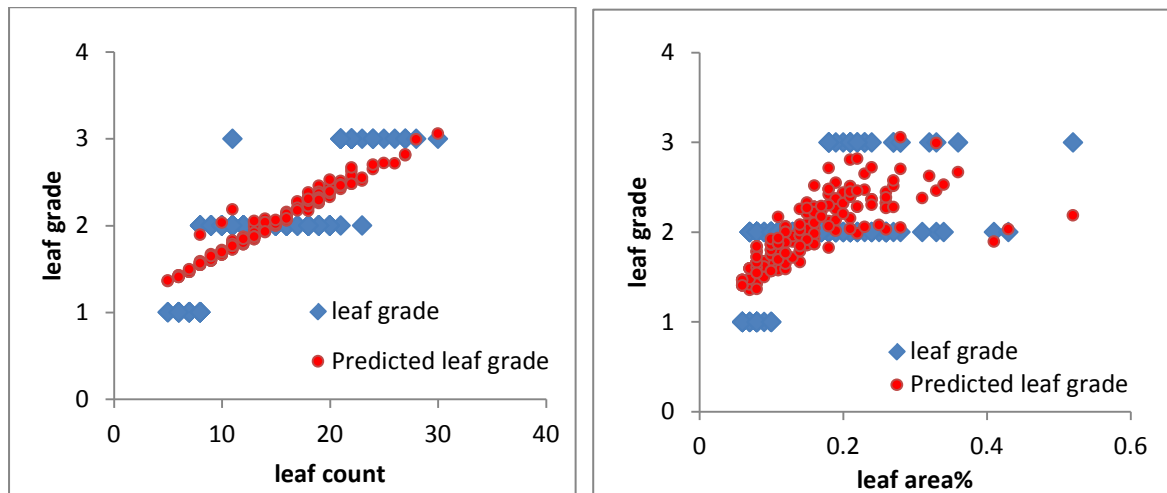


Figure 2 – Line fit plots for HVI leaf grade multiple regression

Multi-regression data fitting assumes that parameters are independent of each other. This is clearly not the case for leaf count and leaf area. For constant size leaves, the two parameters would be proportional to each other. This leads us to explore single-parameter regression.

Leaf count C – leaf grade G regression:

$$LG = 1.0160 + 0.0686 C$$

$R^2 = 0.5480$, with 15 incorrectly assigned grades (7.6%), which is even slightly better than the multi-regression prediction discussed above.

Leaf area A – leaf grade G regression:

$$LG = 1.4436 + 3.5605 A$$

$R^2 = 0.3130$, with 46 incorrectly assigned grades (23.2%), which is worse than both the multi- and the leaf count single-parameter regressions.

The line fit plots for the two single parameter regressions are shown in Figure 3. Single parameter regression based on leaf count is better than that based on leaf area in terms of goodness-of-fit value (R^2) and number of correct predictions of leaf grade bales.

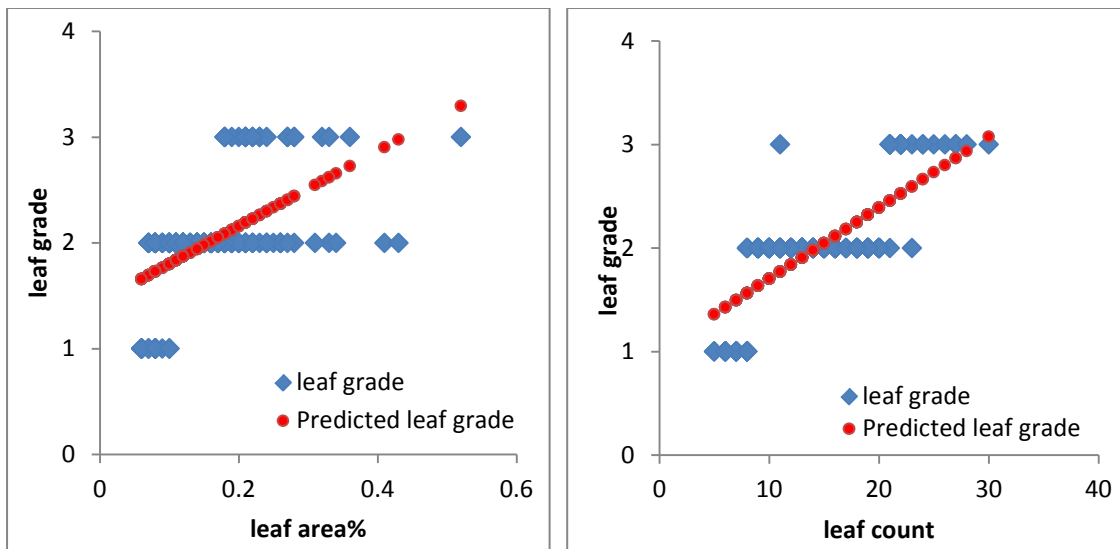


Figure 3 – Line fit plots for single parameter HVI leaf grade regression

We made a comment earlier that leaf area and leaf count are not independent parameters. Now, we have a look at the relationship between the two parameters. As shown in Figure 4, the two parameters show a generally positive correlation although with a relatively low goodness-of-fit value $R^2 = 0.3814$. In other words, leaf area can explain 38.14% of the variation for leaf count, and vice versa. This correlation may be explained by high variability of leaf particle size and possibly particle shape, which are not provided in the datasets.

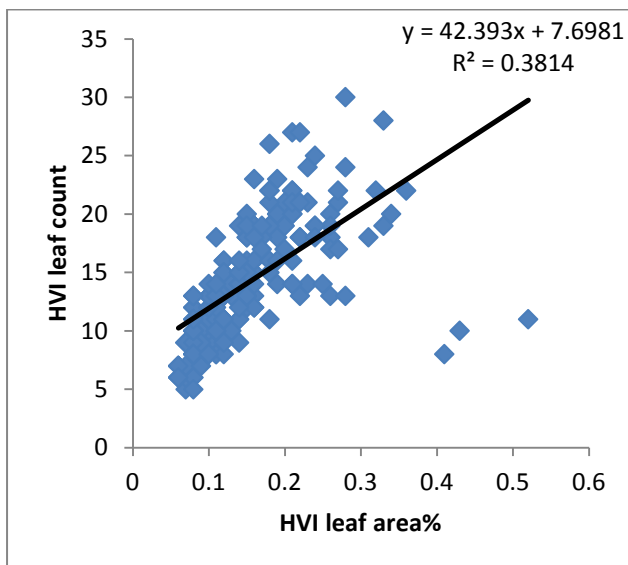


Figure 4 – Correlation between HVI leaf count and leaf area

On the other hand, “relative leaf size” can be calculated from the ratio leaf area/count for each bale. This calculated relative leaf size is plotted according to the leaf grade assigned to each bale in the three regions, as shown in Figure A6 of the Appendix. The calculated average relative leaf size showed a distribution rather than a constant, with a range depending on the number of bales in the grade group. Its value did not show an increase or a decrease with leaf grade assigned to the bales.

The effect of leaf particle size on leaf grade should be investigated further. If trash particle size has little effect on HVI leaf grade (hypothesis at this stage), we could reduce leaf count to improve HVI leaf grade. Fewer large leaf particles are easier to remove than many pepper-sized in leaf particles during cotton spinning. Leaf count may be decreased by reducing

mechanical actions during processing. Reduced mechanical actions during ginning can also lead to longer fibre length, less short fibre content, higher fibre strength and reduced naps.

Individual regional datasets

The same procedure can be used to analysis the datasets from the three regions.

Warren

Two-parameter regression:

$$LG = 0.5341 + 1.3264 A + 0.1073 C$$

Adjusted $R^2 = 0.4835$, with four incorrectly assigned grades out of 65 bales (6.2%).

Single-parameter (leaf count) regression:

$$LG = 0.5301 + 0.1241 C$$

$R^2 = 0.4526$, with eight incorrectly assigned grades out of 65 bales (12.3%).

Single-parameter (leaf area) regression:

$$LG = 1.4047 + 2.5950 A$$

$R^2 = 0.2114$, with 21 incorrectly assigned grades out of 65 bales (32.3%).

Trangie

Two-parameter regression:

$$LG = 0.9853 + 0.0218 A + 0.0695 C$$

Adjusted $R^2 = 0.5811$, with four incorrectly assigned grades out of 66 bales (6.1%).

Single-parameter (leaf count) regression:

$$LG = 0.5301 + 0.1241 C$$

$R^2 = 0.4526$, with four incorrectly assigned grades out of 66 bales (6.1%).

Single-parameter (leaf area) regression:

$$LG = 1.5541 + 3.3418 A$$

$R^2 = 0.2730$, with 13 incorrectly assigned grades out of 66 bales (19.7%).

Narrabri

Two-parameter regression:

$$LG = 1.0946 + 0.5379 A + 0.0568 C$$

Adjusted $R^2 = 0.4255$, with six incorrectly assigned grades out of 67 bales (9%).

Single-parameter (leaf count) regression:

$$LG = 1.1084 + 0.615 C$$

$R^2 = 0.4397$, with eight incorrectly assigned grades (12%)

Leaf area – leaf grade regression:

$$LG = 1.5435 + 3.4216 A$$

$R^2 = 0.2362$, with ten incorrectly assigned grades (14.9%)

The line fit plots for all regressions on the regional datasets are provided in the Appendix (see Figures A3-A5).

The regression analyses based on the three datasets have led to the following conclusions:

- Two-parameter regression based on both leaf count and leaf area provides similar prediction as single-parameter regression based on leaf count.
- Single-parameter regression based on leaf count provides much better prediction than that based on leaf area.

Correlation between leaf count and grade – IntelliGin

The datasets provided leaf grade and leaf count measured by the IntelliGin system. However, corresponding leaf area values were not provided. A single-parameter (leaf count) regression analysis was conducted on the consolidated dataset. The regression summary outputs are given in Table 3.

Table 3 – Regression summary outputs for consolidated IntelliGin leaf grade dataset

<i>Regression Statistics</i>					
Multiple R	0.887178259				
R Square	0.787085263				
Adjusted R Square	0.785998963				
Standard Error	0.295881528				
Observations	198				
ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	63.43192	63.43192	724.5563	9.35E-68
Residual	196	17.15899	0.087546		

Total 197 80.59091

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	0.778874223	0.051539	15.11243	1.02E-34
leaf count	0.093891016	0.003488	26.91758	9.35E-68

We obtained the following regression equation:

$$LG = 0.7789 + 0.0939 C$$

The relationship is plotted in Figure 5. The goodness-of-fit for this regression $R^2 = 0.7871$ is much higher than that from the HVI dataset; 193 out of 198 bales were predicted correctly using this regression equation, i.e. the incorrect prediction rate was 2.5% (5 out of 198 bales). Correlations between IntelliGin leaf count and leaf grade for individual regions are presented in Figure A7 of the Appendix.

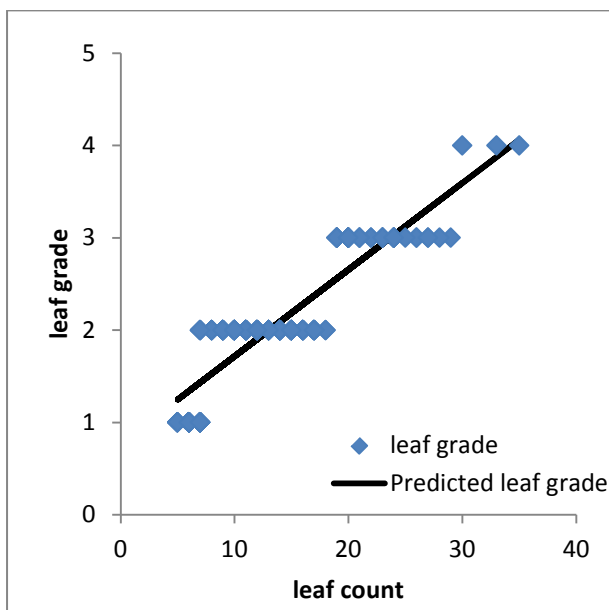


Figure 5 – Correlation between IntelliGin leaf count and leaf grade – consolidated dataset

Leaf grade differences between HVI and IntelliGin

Figure 6 compares the number of bales assigned to each leaf grade by the HVI and IntelliGin methods. The average leaf grade was 1.995 assigned by HVI and 2.045 by the IntelliGin. So the difference between the averages was very small (0.05 grade). At first glance, the two distributions seem to be reasonably consistent. But this is not true when we examine the grade assigned to individual bales by the two methods. Of the 198 bales, only 113 bales were assigned the same leaf grade by the two systems (57%). The HVI assigned 39 bales with a leaf grade that was one grade lower than that assigned by the IntelliGin, 43 bales with one grade higher than the IntelliGin and 3 bales with two grades higher than the IntelliGin. The grade differences for individual bales are shown in Figure 7.

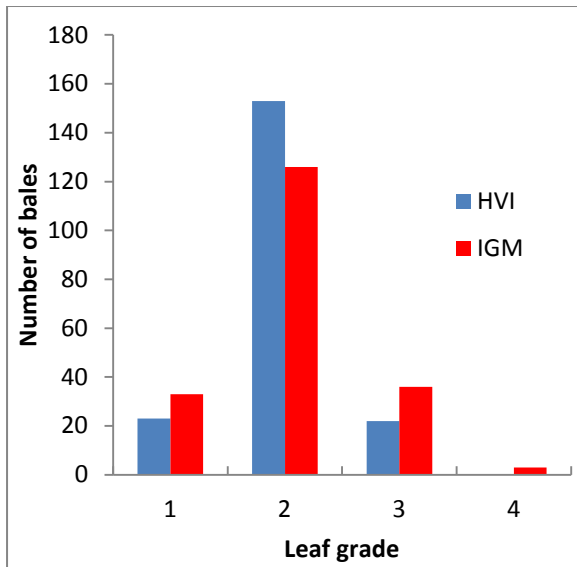


Figure 6 – Leaf grade distributions from the consolidated dataset according to HVI and IntelliGin (IGM) measurements

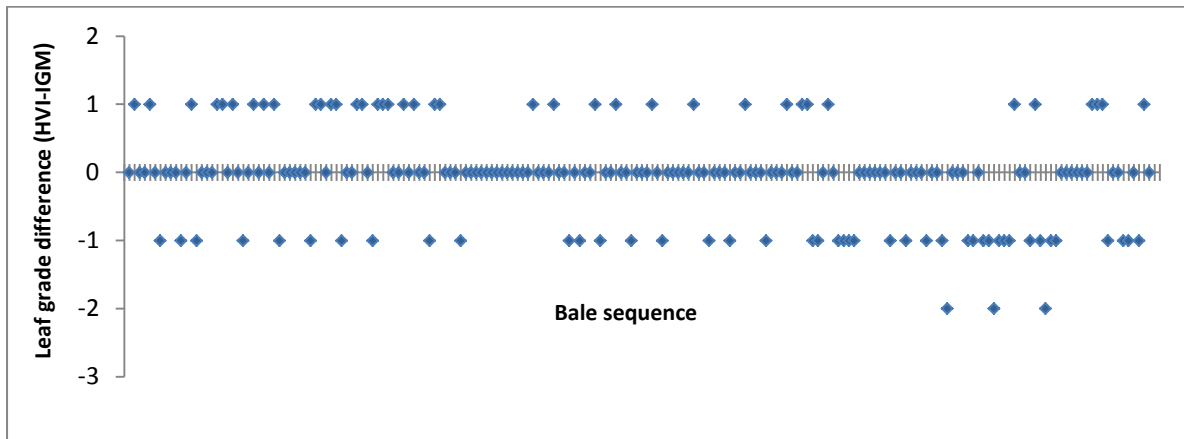


Figure 7 – Differences in leaf grades assigned to individual bales by HVI and IntelliGin (IGM) systems

We found in the previous section that leaf count was a good predictor of leaf grade for both HVI and IntelliGin systems. Overall, the average leaf count was 14.26 (standard deviation = 5.15) by HVI, and 13.49 (SD = 6.04) by IntelliGin. So they are reasonably consistent.

We now compare the leaf counts of individual bales measured by the two systems. This is plotted in Figure 8. Bales sitting directly on the red diagonal line were assigned with the same leaf count value by both systems. Bales falling below the red line are assigned with a higher leaf count by the HVI system, and bales falling above the red line are assigned with a lower leaf count by the HVI system. The black line is the regression between the two leaf count methods. The goodness-of-fit ($R^2=0.2218$) is quite low because of the wide spread of data. So the agreement between leaf counts measured by the two systems was quite low.

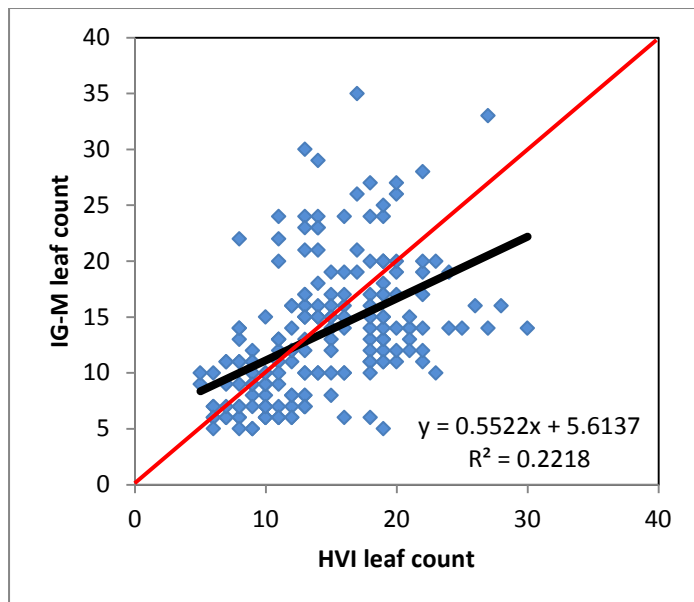


Figure 8 – Comparison of leaf counts measured by HVI and IntelliGin systems

We conducted similar analysis on the datasets from the three regions and presented the results graphically in the Appendix (Figures A8 – A10). The Narrabri dataset showed the highest consistency of leaf grade between HVI and IntelliGin (49 out of 67 bales assigned to same grade), followed by Warren (33 out of 65 bales assigned to same grade) and Trangie the lowest (31 out of 66 bales assigned to same grade). In fact all the three bales that showed with a two-grade difference in Figure 7 were from Trangie. There was similarly little correlation between the HVI measured leaf count and IntelliGin measured leaf count for all the three regions.

Colour grade

The official colour grades for American Upland cotton encompass twenty-five colour grades and five categories of below grade colour, see **Error! Reference source not found.** in the Appendix.

Cotton colour grade can be determined using high volume instruments (HVI) by referencing to the Nickerson-Hunter colour diagram. The Nickerson-Hunter colour diagram (**Error! Reference source not found.**) was established from measurements of the universal standards for American Upland cotton using a Nickerson-Hunter colorimeter [7]. The Nickerson-Hunter diagram is permanently stored in the HVI colorimeter. Rd (Reflectance, or brightness) and +b (yellowness) readings are recorded to the nearest 0.1 scale unit, and the corresponding colour grades generally are correlated with the visual grades [8]. The HVI colorimeter measures the degree of reflectance (Rd) and yellowness (+b) of a cotton sample, and determines the colour grade by locating the point at which the Rd and +b values intersect on the Nickerson-Hunter cotton grade diagram. A three-digit code is used, for example, 21-3. The first digit (2) is the brightness as indicated by percent reflectance of light in terms of Rd unit. The second digit (1) is the degree of yellowness expressed in terms of +b. The third digit (3) is a combination of brightness and yellowness; where the colour grade is subdivided into quadrants to denote slight colour differences within that grade.

The IntelliGin provides a two-digit colour code, corresponding to the first two digits of the three digit HVI colour code.

Relationship between Rd and +b, and colour grade

A survey of the datasets showed that the second digits (yellowness) of all the colour grades assigned by both HVI and IntelliGin were “1”, i.e., they were all classified as “white”. The IntelliGin system does not provide information on colour quadrant (third digit in HVI colour code), so we need only to consider the first digit, i.e., colour (brightness) grade, in our analyses.

Consolidated dataset - HVI colour grade

The regression analyses of the colour grade (CG) were conducted using a similar approach as for the leaf grade. The two-parameter regression results using Rd (Rd) and +b (B) are summarised in Table 4 and Figure 9.

Table 4 – Summary outputs of a multi-parameter regression for the HVI consolidated dataset

<i>Regression Statistics</i>	
Multiple R	0.861683
R ²	0.742498
Adjusted R ²	0.739857
Standard Error	0.286971
Observations	198

<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	2	46.3049	23.15245	281.1384	3.56E-58
Residual	195	16.05874	0.082352		
Total	197	62.36364			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	39.03535	1.602246	24.3629	4.52E-61	35.8754	42.19531
Rd	-0.37865	0.018819	-20.1198	1.83E-49	-0.41576	-0.34153

+b	-0.78338	0.074734	-10.4823	1.12E-20	-0.93077	-0.63599
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The resulting multi-regression equation is

$$CG = 39.0354 - 0.3787Rd - 0.7834 B,$$

with an adjusted $R^2 = 0.7399$ i.e., nearly 74% of the variation of the brightness grade around the mean is explained by the reflectance (Rd) and yellowness (+b). This goodness-of-fit for brightness grade is considerably better than that for leaf grade (adjusted $R^2 = 0.5605$); 183 grade values out of 198 were predicted correctly by this regression equation, and 15 bales (7.6%) were not predicted correctly.

From the ANOVA table, the F-test statistic is 281.1 with a p-value of 3.56×10^{-58} . This leads to the conclusion that the parameters jointly are very highly significant. When the two parameters are examined separately, we find t-statistic is -20.1 for Rd ($p = 1.83 \times 10^{-49}$) and -10.48 for leaf count ($p = 1.12 \times 10^{-20}$). Therefore both parameters are highly significant in the determination of colour grade.

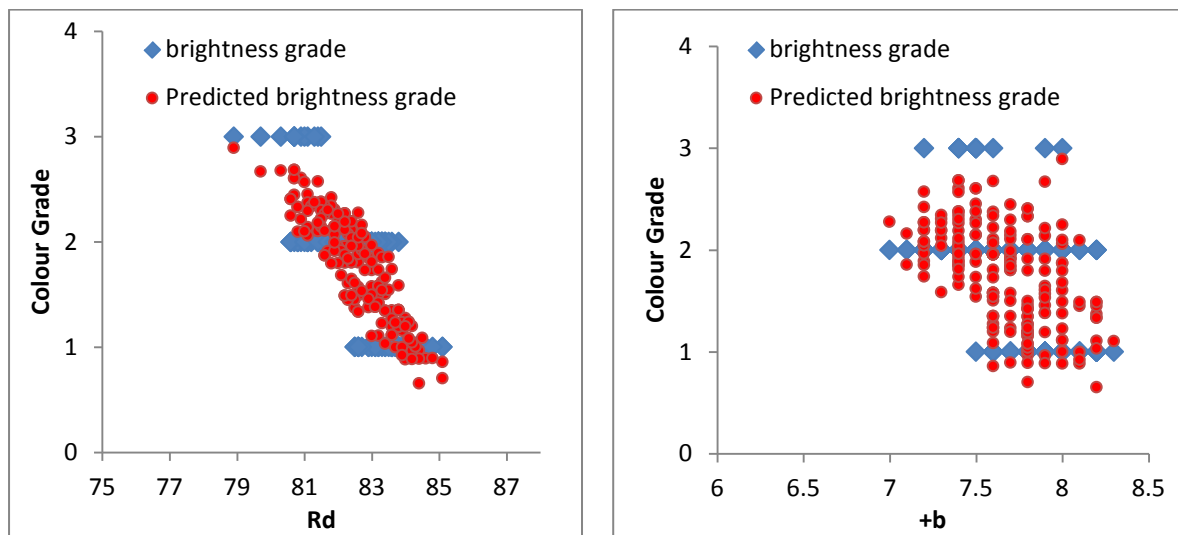


Figure 9 – Line fit plots of HVI colour grade regression analysis with Rd and +b for the consolidated dataset; blue points are colour ‘brightness’ grade values, red points are predicted colour ‘brightness’ values

The regression equation shows that the colour grade CG is negatively correlated to both reflectance and yellowness. Note that a smaller CG value represents a better grade. This means that high values of both Rd and +b are desirable, as shown by the two arrows in Figure A2. In particular, at a given Rd value, a slightly higher +b value tends to lead to a higher brightness grade. This is a deviation from the apparent but naïve assumption that a lower +b value is always better for colour grade. The expected adverse effect of increasing +b value on pigment grade (yellowness) did not happen in all the bales studied here because their +b values were all at low levels, i.e., below the threshold between “white” grade and “light spotted” grade.

Regression analyses for the three regional datasets are presented graphically in Figure A11 of the Appendix.

Consolidated dataset - IntelliGin colour grade

The resulting multi-regression equation is

$$CG = 36.6660 - 0.3407 Rd - 0.8834 B$$

with an adjusted $R^2 = 0.8286$ i.e., nearly 83% of the variation of the brightness grade around the mean is explained by the reflectance (Rd) and yellowness (+b). The goodness-of-fit is therefore even higher than that for the HVI method ($R^2 = 0.7399$); 187 grade values out of 198 were predicted correctly by this regression equation, and 11 bales (5.6%) were not predicted correctly. The regression summary is given in Table 5.

Regression analyses for the three regional datasets are presented graphically in Figure A12 of the Appendix.

Table 5 – Summary outputs of multi-regression for the consolidated IntelliGin dataset

<i>Regression Statistics</i>						
Multiple R	0.911237					
R ²	0.830352					
Adjusted R ²	0.828612					
Standard Error	0.302058					
Observations	198					
<i>ANOVA</i>						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	2	87.08215	43.54108	477.2206	7.6E-76	
Residual	195	17.79158	0.091239			
Total	197	104.8737				
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	36.66595	1.122609	32.66138	5.31E-81	34.45194	38.87996
Rd	-0.34074	0.011523	-29.5706	5.44E-74	-0.36347	-0.31801
+b	-0.8834	0.053005	-16.6664	2.35E-39	-0.98793	-0.77886

Colour (brightness) grade difference between the two systems

Figure 10(a) compares the number of bales assigned to each brightness grade by the HVI and IntelliGin systems. The average brightness grade assigned by HVI (1.758) was 0.268 grade better than the average grade assigned by IntelliGin (2.025). As shown in Figure 10(b), of the 198 bales, only 80 bales were assigned the same grade by both systems (40%). HVI assigned 36 bales with a brightness grade that was one grade lower than that assigned by IntelliGin (18%), 75 bales one grade higher than IntelliGin (38%) and 7 bales two grades higher than IntelliGin (3.5%). Note that a high colour grade has a lower number, for example, a “grade 1” (Good Middling) is better than a “grade 2” (Strict Middling) and so on. The distribution of grade differences for individual bales is shown in Figure 10(c). Clearly, the agreement between the two systems was rather poor.

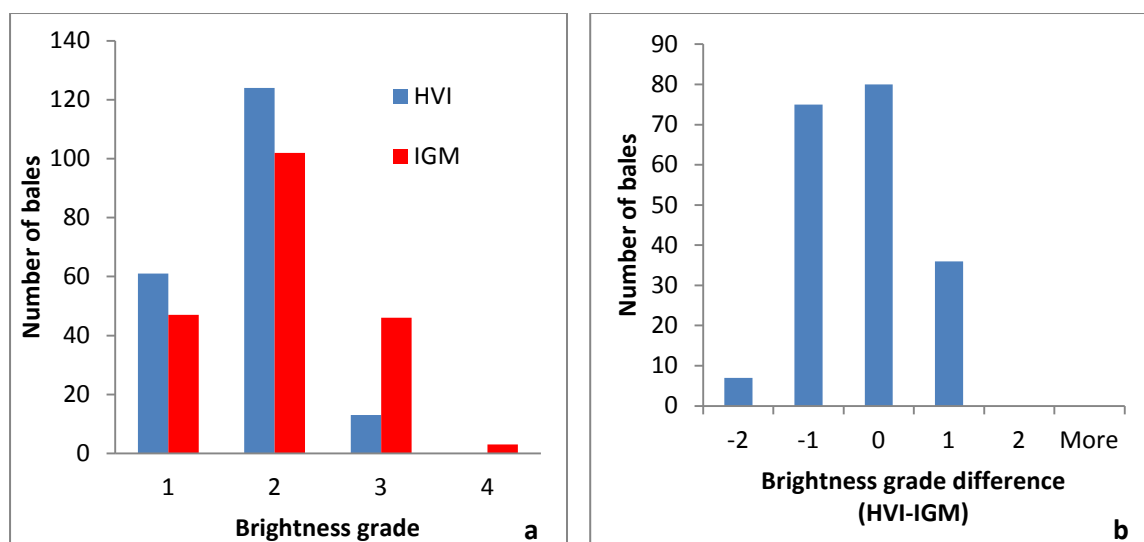


Figure 10(a) – Colour grade (brightness) distributions from the consolidated dataset according to HVI and IntelliGin (IGM) measurements; Figure 10(b) distribution of differences in colour (brightness) grade

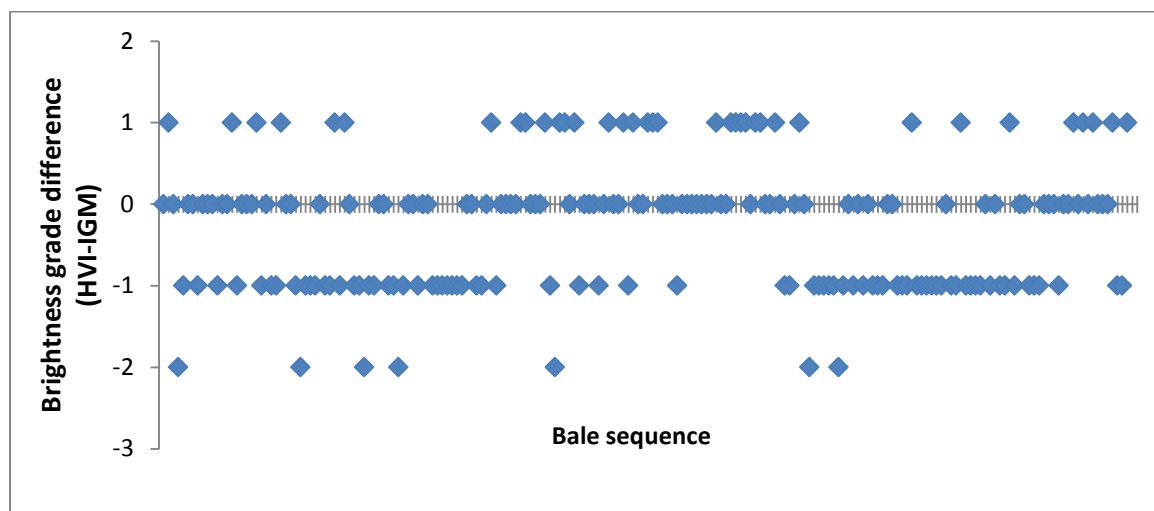
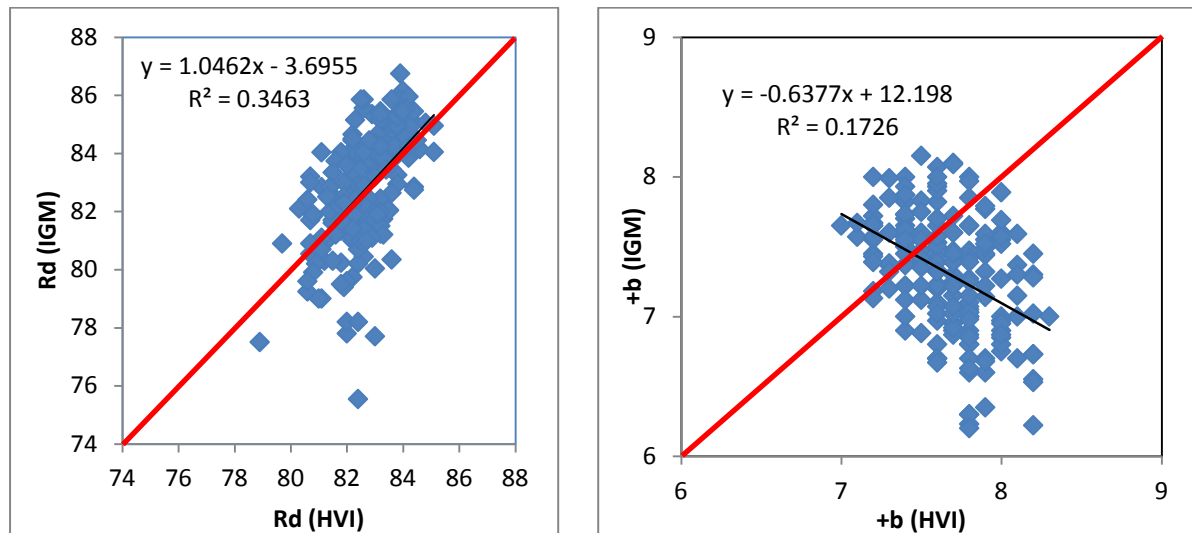


Figure 10(c) – Differences in colour (brightness) grades assigned to individual bales by HVI and IntelliGin (IGM) systems

As the colour grade is derived from Rd and +b values, we can trace the origin of grade difference to these colorimetrics obtained by the two systems. Overall, the average Rd was 82.59 (standard deviation = 1.09) by HVI, which is consistent with 82.71 (SD = 1.94) by the IntelliGin. The average +b value was 7.66 (standard deviation = 0.27) obtained by HVI, which was 0.3 greater than 7.31 (SD = 0.42) by IntelliGin. The relationship of colorimetrics for individual bales measured by the two systems is plotted in Figures 11(a) and (b). Ideally,

the two systems should give the same data for each bale and thus all the data points should sit directly on the red diagonal lines. This is clearly not the case. The Rd values produced by the two systems showed a low level of positive correlation with a goodness-of-fit $R^2=0.3463$. The +b values measured by the two system were basically uncorrelated with each other ($R^2=0.1726$ for a negative correlation trend, which was unexpected). So the agreement between colorimetrics measured by the two systems was very poor. The small differences between their average values were basically due to the small range of the data.



Figures 11(a) and (b) – Comparison of (a) Rd and (b) +b measured by HVI and IntelliGin (IGM) systems

USDA guidelines [6] for permitted tolerances for HVI instruments in different laboratories are 1.0 unit for Rd, 0.5 unit for +b, and 0.1% area for trash. These tolerances for HVI instruments do not govern the differences between HVI and IntelliGin system. The differences between one HVI instrument and one IntelliGin instrument cannot be found from public literature but are likely greater than the permitted tolerances between HVI instruments in different laboratories.

In the studied dataset (including all three regions), the value range was 6 units for Rd, 1.3 unit for +b, and 0.3% for leaf area. These are quite small ranges relative to the instrument tolerances, especially for +b the value range being only 2.6 times of the tolerance for HVI instruments.

Comparison with HVI results on grab samples

As mentioned earlier, although IntelliGin and HVI are manufactured by the same company, the HVI system measures samples from bales that have been pressed to a high density while the IntelliGin system takes measurement from previously uncompressed cotton. The compression history, as well as the more difficult conditions of obtaining a consistent specimen for the IntelliGin system means that the digital images of specimens are not identical for the two systems.

To further understand the causes of the differences of data between the two systems, grab samples were taken at a location near where the IntelliGin system was installed. The grab samples, which were not compressed, were then tested on HVI and the results compared with corresponding results measured and attributed to bales by HVI and the IntelliGin. The grab samples represent the production of one hour in the Warren gin on cotton similar (same variety/growing region) to the samples identified in Section 1.1 from the Warren gin. In this way, differences between IntelliGin and the HVI tests on grab samples may be attributed to

instrument and/or testing conditions (for example, lighting), and the difference between the HVI test on bale and the HVI test on grab samples may be attributed to cotton compression (baling).

The reflectance and leaf area/leaf count values from the three types of measurements are shown in Figures A17 and A18 in the Appendix. Clearly, there is little correlation between any two measuring methods. The average colour and leaf parameters from the three measurements are summarised in Table 6.

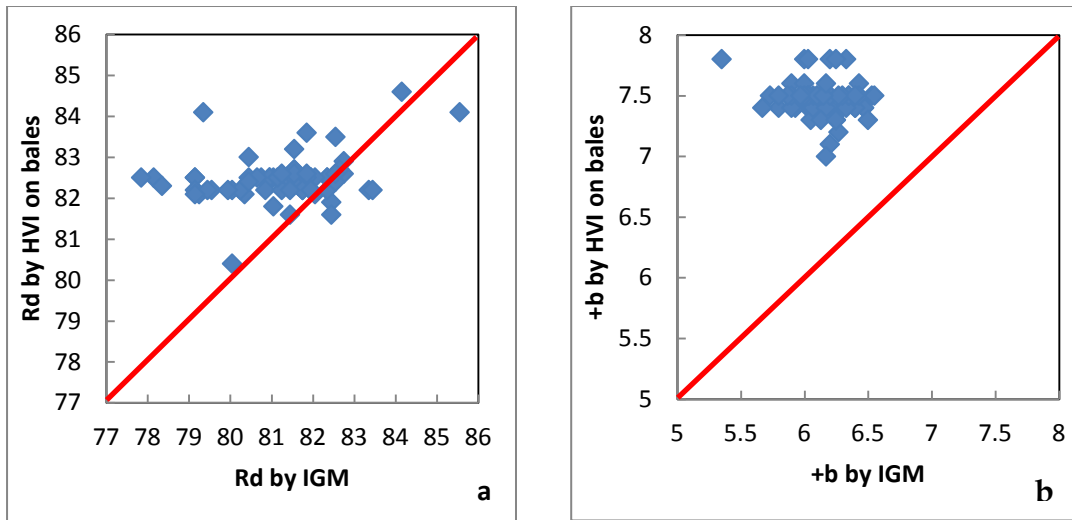
Table 6 – Average results from IntelliGin (IGM), HVI on bales (65 bales) and HVI on grab samples (40 grab samples) taken within same hour

	IntelliGin		Bale HVI		Grab HVI	
	Ave	StDev	Ave	StDev	Ave	StDev
Colour (Rd) grade	3.25	0.50	1.97	0.30	2.83	0.45
Rd	81.2	1.43	82.5	0.58	79.6	1.0
+b	6.13	0.22	7.47	0.15	7.69	0.36
Leaf grade	2.12	0.52	2.83	0.42	2.33	0.53
Area	0.15	0.05	0.30	0.14	0.23	0.12
Count			21.98	3.10	18.05	5.45

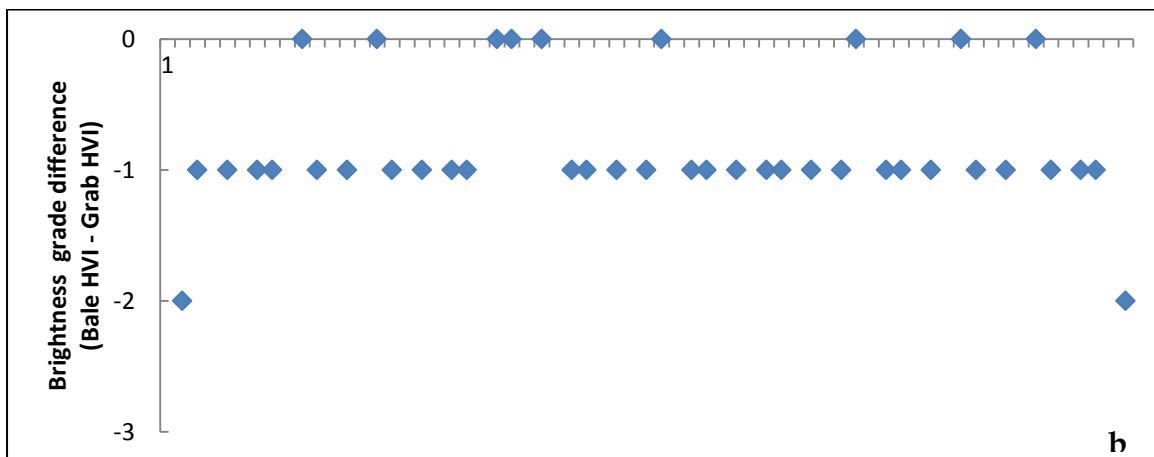
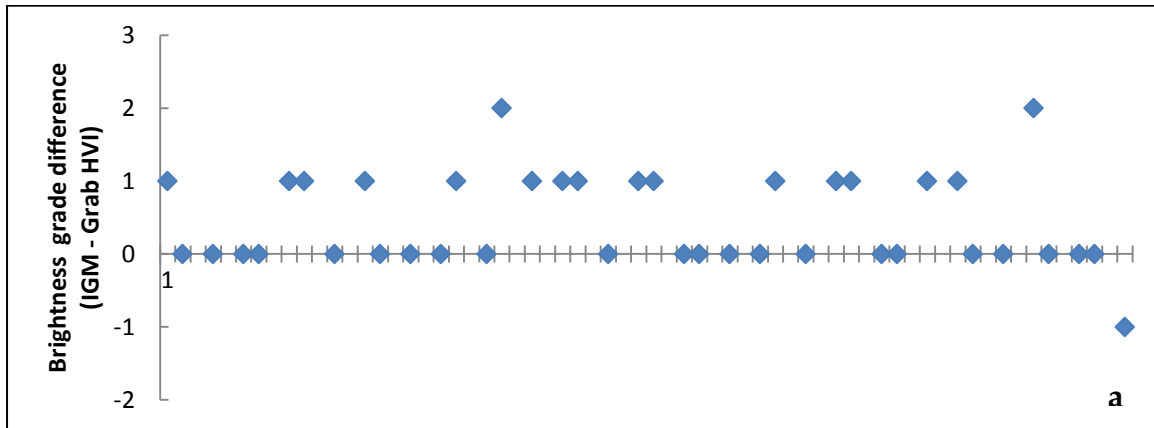
Colour

The average brightness grade for the IntelliGin (3.25) is 1.28 grades worse than that for the lowest for HVI on bales (1.97). This difference is much larger than the differences between the two systems in the three-region datasets. The differences in average Rd and +b values between the two systems are also much greater than that in the three-region datasets. As shown in Figures 12(a) and (b), the data points are far away from the red diagonal line.

The difference between IntelliGin and HVI on grab samples (0.42 grade) could be attributed to instrument, and the difference between HVI on bales and HVI on grab samples (0.86 grade) may be attributed to compression of cotton caused by baling. The average Rd value of grab samples measured by HVI was greatest amongst the three methods and the average +b value was the lowest amongst the three methods. Differences in colour grade assigned to individual samples by IntelliGin, HVI on bales and HVI on grab samples are shown in Figures 13(a) and (b). The grades from HVI on grab samples showed a better match with that from IntelliGin than that from HVI on bales.



Figures 12(a) and (b) – Comparison of (a) Rd and (b) +b measured by HVI and IntelliGin (IGM) systems



Figures 13(a) and (b) – Differences in colour grade assigned to individual samples by IntelliGin (IGM), HVI on bales and HVI on grab samples

Leaf

Of the 65 bales (Figure 14(a)), 21 bales were assigned the same leaf grades by the HVI on bale method and the IntelliGin method (32% agreement level). This is much lower than the agreement level by the same methods for the three region datasets (57%).

Of the 40 grab samples, 20 (50%) were assigned to the same leaf grades as that by the IntelliGin method (Figure 14 (b)), 18 (45%) were assigned to the same leaf grades as that by the HVI on bale method (Figure 14(c)). These are better than the agreement levels on the same batch by the IntelliGin method and the HVI on bale method, but still not as good as those for data from the three regions.

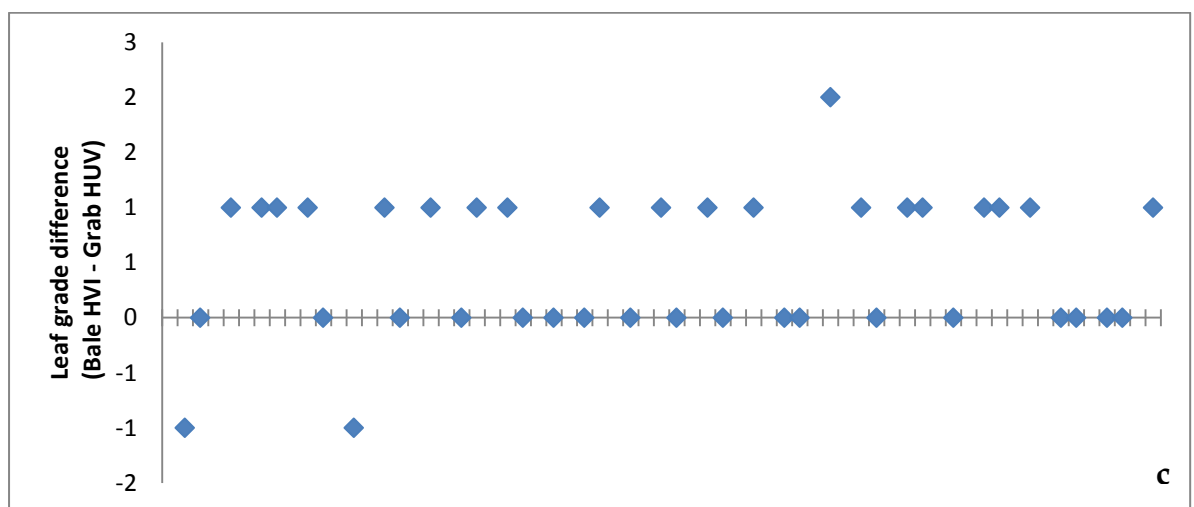
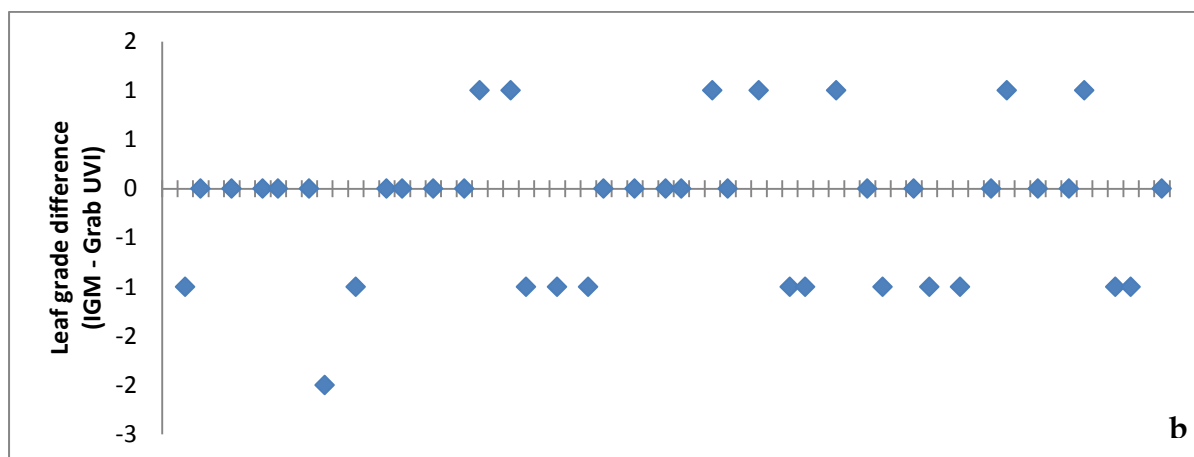
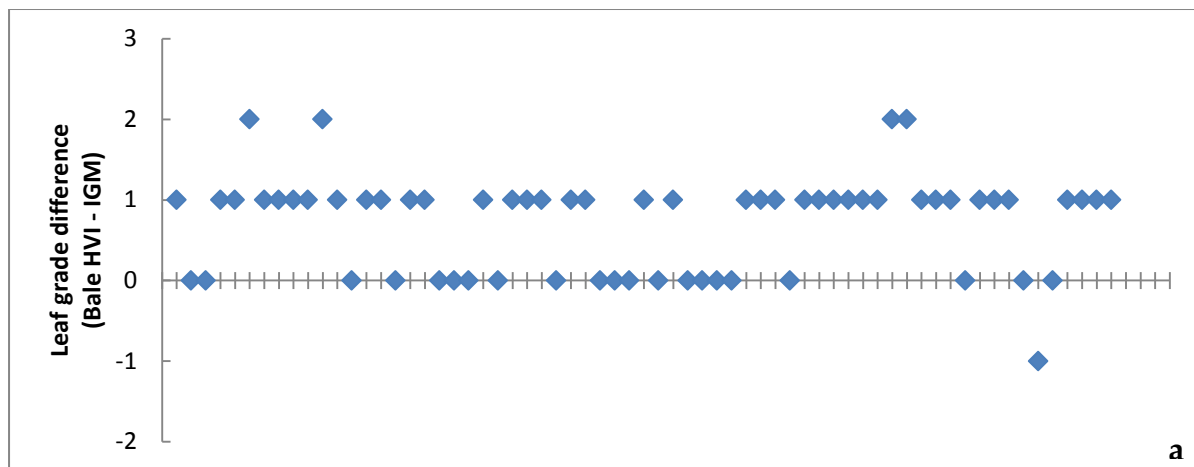
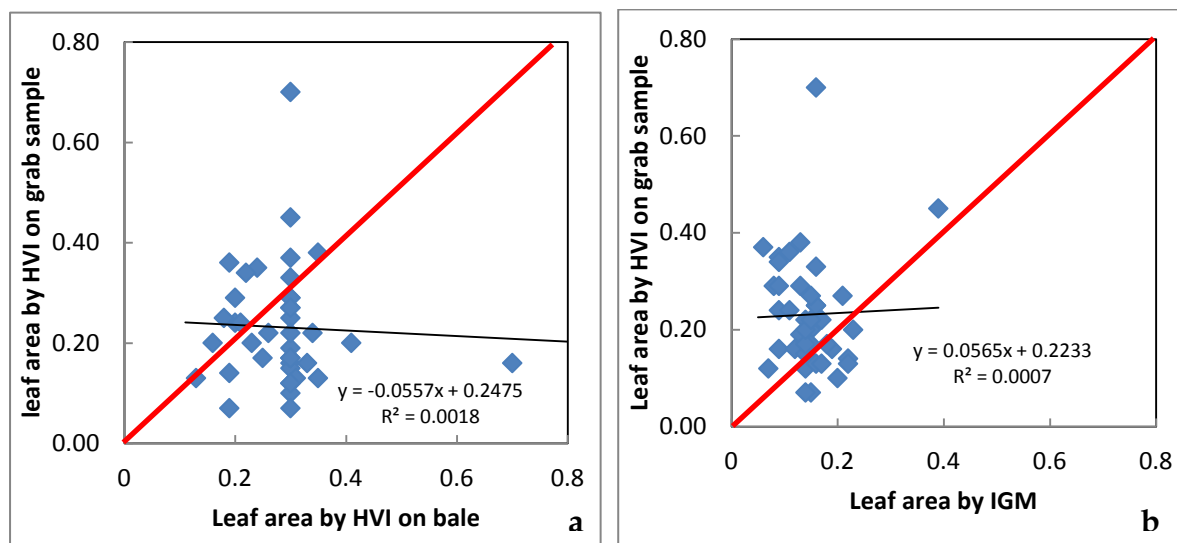


Figure 14(a) (b) and (c) – Differences in leaf grade assigned to individual samples by IntelliGin (IGM), HVI on bales, and HVI on grab samples

Figures 15(a) and (b) show the relationship of leaf area by HVI on grab samples with that by HVI on bales (left) and by IntelliGin (right), respectively. There is no obvious correlation between these measuring methods for the period examined.



Figures 15(a) and (b) – Correlation of leaf area by HVI on grab samples with that by (a) HVI on bales and by (b) IntelliGin (IGM)

References

- [6] USDA. The Classification of Cotton. Agricultural Handbook 566, 1993.
- [7] ASTM. D2253: Color of Raw Cotton Using the Nickerson-Hunter Cotton Colorimeter. 1990.
- [8] Xu B, Fang C, Huang R, Watson M. Cotton Color Measurements by an Imaging Colorimeter. Textile Research Journal. 1998;68:351-358.

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

The planned outcomes for the project were to deliver an assessment of current in-line gin monitoring systems for industry. The assessment would highlight the relations between measured values by the gin system and those by the HVI system. The potential for in-line systems in gins to monitor and control fibre quality has long been understood. Realisation of this potential whereby data from multiple monitors are networked to provide information on cotton quality requires objective information for the market and viable alternatives to the current technology.

The assessment has been completed.

6. Please describe any:-
 - a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);
 - b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
 - c) required changes to the Intellectual Property register.

No changes to IP used as background or generated during this project.

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

In this project, we studied the statistical relationships of leaf and colour grades measured by HVI instrument on baled cotton and IntelliGin system during ginning. The datasets with corresponding HVI and IntelliGin results were supplied from three ginning regions, Warren, Trangie and Narrabri. Each region provided 65-67 sets of data representing about 200 bales (data taken from every three bales). All the data were collected during May 2013. This is a small snap shot for the scale of the Australian cotton production. In the studied dataset, the value range was 6 units for Rd, 1.3 unit for +b, and 0.3% for leaf area. These are quite small ranges relative to the instrument tolerances, especially for +b the value range being only 2.6 times of the tolerance for HVI instruments.

Although IntelliGin and HVI instruments are manufactured by the same company, HVI system measures on samples taken from bales that have been pressed to high density while IntelliGin system takes measurement from previously uncompressed cotton. The lighting conditions for taking photographic images are not identical for the two instruments. The USDA guidelines [6] for permitted tolerances for HVI instruments in different laboratories are 1.0 unit for Rd, 0.5 unit for +b, and 0.1% area for trash. These permitted tolerances for HVI instruments do not govern the differences between HVI and IntelliGin system. The differences between one HVI instrument and one IntelliGin instrument cannot be found from the literature but are likely greater than the permitted tolerances between HVI instruments in different laboratories. Additional grab samples were tested to differentiate the error caused by the instruments by compression of the cotton specimen applied when the cotton was baled.

While the values analysed were very typical of Australian cotton, the limited range of values constrained the ability of the dataset to show more fully the relationship between the instruments.

The main findings from this study are:

- Leaf count was found to be a better regressor for leaf grade than leaf area, although the USDA classification standard stipulates that leaf area is correlated to classer grade. The implication of this is that removing leaves from cotton by mechanical actions during processing may not be the preferred option. Leaf count may be decreased by reducing mechanical actions during processing, leading to smaller number of larger leaf particles rather than large number of pepper-sized particles. Reduced mechanical actions reduce mechanical damages to cotton and will be beneficial to cotton quality (for example, fibre length and strength). In addition, fewer large leaf particles are easier to remove than many pepper-sized leaf particles during cotton spinning. We recommend a further study on this strategy.
- All bales examined were assigned the best pigmentation grade “white”, i.e. no samples were classed as “spotted” or worse. The +b values of all bales was consistently low (very few bales had +b values above 8) in terms of yellowness. The low +b values had an adverse effect on the USDA classing grade that was applied to the cotton. This matters particularly in the movement of the grade from Middling to Strict Low Middling,

which carries a large discount on the cotton. In other words, a superior attribute of these cottons was penalised according to the current colour standard designed for American Upland Cotton. We understand this issue is being looked at currently by the Cotton Classers Association of Australia. This study provides more evidence for an opportunity to market Australian cotton as being “super white (very low +b value).

- Overall average leaf and colour grades from the two systems were quite consistent. However, grades and values assigned to individual bales differed widely. Overall, 57% of the bales were assigned to the same leaf grade by the HVI and IntelliGin; 40% of the bales were assigned the same brightness grade by the two systems.
- Very large differences in average values were found from the results measured by IntelliGin and that by the HVI on bales for the additional batch of grab samples examined. These differences could be attributable to the sampling rate of the manual grab versus the IntelliGin grab and baling rate and the compression history of the samples, as well as the instrument differences observed in the comparison between paired HVI and IntelliGin values from the three regions. However, without more consistent data these conclusions remain speculative.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:
 - (a) to further develop or to exploit the project technology.
 - (b) for the future presentation and dissemination of the project outcomes.
 - (c) for future research.

These results will be related to Australian Cotton Ginners Association members and to the manufacturer of the IntelliGin, Uster Technologies. Responses to the project’s conclusions will be sought from Uster. At this stage the results will not be published in a peer review journal.

8. A. List the publications arising from the research project and/or a publication plan.
(NB: Where possible, please provide a copy of any publication/s)

At this stage the results will not be published in a peer review journal.

- B. Have you developed any online resources and what is the website address?

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

The objectives of this project were to compare results from Uster Technologies IntelliGin system, an in-line leaf, colour and moisture monitor for cotton ginning, with leaf and colour grade results from the standard High Volume Instrument (HVI), also built by Uster. We studied the statistical relationships between the leaf and colour grades measured by HVI instrument with those measured by the IntelliGin system. The datasets with corresponding HVI and IntelliGin results were supplied from three gins representing three growing regions. From each region between 65 and 67 sets of HVI data, representing about 200 bales after module averaging, were gathered. While this is only a small snap shot of Australian cotton production, the dataset reflects standard leaf and colour grade values found in Australian cotton. It is noted the subsequent relationships measured would have been improved with a larger set of samples containing a wider range of USDA leaf and grade classifications.

The main findings from this study are:

- Leaf (particle) count was found to be a better regressor for leaf grade than leaf (particle) area, although the USDA classification standard stipulates that leaf area is correlated to classer grade. The implication of this is that removing leaf from cotton by mechanical actions during ginning may not be the preferred option. Leaf count may be decreased by reducing mechanical actions during processing, leading to smaller number of larger leaf particles rather than a large numbers of pepper-sized particles. It is well documented that reduced mechanical action in the gin reduces the amount of damage to cotton and is generally beneficial to cotton quality in terms of fibre length and neps. In addition, fewer larger leaf particles are easier to remove than many pepper-sized leaf particles during cotton spinning. We recommend further study on this strategy.
- All bales examined were assigned the best pigmentation grade “white”, i.e. no samples were classed as “spotted” or worse. The +b values of all bales was consistently low (very few bales had +b values above 8) in terms of yellowness. The low +b values had an adverse effect on the USDA classing grade that was applied to the cotton. This matters particularly in the movement of the grade from Middling to Strict Low Middling, which carries a large discount on the cotton. In other words, a superior attribute of these cottons was penalised according to the current colour standard designed for American Upland Cotton. We understand this issue is being looked at currently by the Cotton Classers Association of Australia. This study provides more evidence for an opportunity to market Australian cotton as being “super white (very low +b value).
- Although the overall average values of leaf and colour grades from the two systems were quite consistent the values assigned to individual bales differed widely. Overall, 57% of the bales were assigned to the same leaf grade by the HVI and the IntelliGin; 40% of the bales were assigned the same brightness grade by the two systems.

- Very large differences in average values were found in the results measured by IntelliGin and by the HVI on bales, for the additional batch of grab samples examined. These differences could be attributable to the sampling rate of the manual grab versus the IntelliGin grab and baling rate, and the compression history of the samples, as well as the instrument differences already observed in the comparison between paired HVI and IntelliGin values from the three regions. However, without more consistent data these conclusions remain speculative.