LATEST DEVELOPMENTS AND RESULTS IN AUTOMATIC SCF COUNTING, PART II: IMPROVED IMAGE ACQUISITION AND RESULTS OBTAINED

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Summary

The Trashcam project developed a rapid, automated method used to evaluate the seed coat fragment (SCF) potential of fibers from new cotton plant lines. A camera is used to acquire an image of the fiber web and this is then analyzed by image processing. The latest version of the product, has improved image quality by using a scanner for image acquisition. We compare the automated counts obtained with counts made by an "expert" in 166 cotton web images. Thanks to the new image acquisition technique and an algorithm whose parameters may be adjusted, the results obtained show that the square root of the automated counts are proportional to the square root of the visual counts. The relationship between the two counts obtained in the context of varietal improvement trials was:

square root of the automated count = 1.00 * square root of the visual count (r=0.965).

Introduction

Seed Coat Fragments (SCF) are fragment of the coat torn off cotton seeds. These impurities disrupt subsequent cotton spinning processes by creating irregularities in the yarn, or lead to production stoppages (Frydrych, 1989, 1992; Schenek, 1992; Jones, 1996; Aubry and Renner, 1996).

Frydrych (1989, 1992), Gourlot *et al* (1995), Bachelier (1996) and Giner *et al* (1997) showed that the character: 'number of SCF in the fiber' is genetically inherited. This heritability can be demonstrated using two different counting techniques: analysis of the yarn using a Zellwegger Uster III regularimeter, and image analysis of card web using the Trashcam.

Evenness measurements of the yarn requires considerable investment (both in time and money) to produce sufficient yarn to be analyzed. But when conducting varietal improvement programs, several years of selection are required (7 to 10) to obtain sufficient fiber for spinning tests. Thus, this eveness measurement provides information concerning SCF potential too late to be useful in selection of new lines during improvement programs. Using this method, the time required to produce SCF-free varieties is excessively long and cannot meet the expectations of textile producers whose processing equipment is changing more rapidly (Aubry and Renner, 1996).

Trashcam is a test device that avoids the requirement to manufacture yarn and analyze each imperfection of this yarn on a regularimeter using Frydrych (1989, 1992) methods. The Trashcam analyzes an image of the card web prepared in the following manner: about 10 grams of cotton are mixed on our laboratory opener. The fiber web is rolled around a cylinder on leaving the opener. This web is cut into four parts that are placed one on top of the other on entering our laboratory card (Shirley Platt). Four layers of fiber web are rolled around the reception cylinder to form the test web. The Trashcam then acquires the images. Two or three images are taken of each web and are then analyzed. An algorithm is then employed to analyze each image and the results obtained are transferred to the Windows interface which can present these results in 3 forms (histogram of size distribution, image where SCF detected are put forward, ASCII files).

This method, which uses only small quantities of fiber, is able to characterize a large number of samples very early in selection programs (third year after crossing). The results presented by Giner *et al* (1997) show that even though the process is already effective, it can still be improved. The quality of the image acquired was seen to be the limiting factor in counting SCF and determining their morphological characteristics. Indeed, when images of fiber webs acquired by the camera were counted by the "expert" and by the algorithm, both encountered problems in differentiating SCF borders when parts of these were covered by fibers. This phenomenon occurs when the gray level values attributed to the spots (SCF) are too close to those attributed to the background (fibers).

The Trashcam process is sequential: production of the web, image acquisition, image analysis, results. Giner *et al* (1997) have shown that the quality of this image acquisition phase may be improved to provide a more accurate evaluation of SCF potential from a sample of cotton fiber.

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Analysis of Points to Be Improved

One solution is to increase the contrast between these pixels that are difficult to differentiate. This requires:

- improving lighting quality in such a manner to obtain uniform illumination of the sample over its entire surface area,
- increasing the number of points per unit distance to provide a more precise evaluation of the variations observed in the color of the fiber web. This would increase the local contrasts within the image.

The previous Trashcam image acquisition device (Giner *et al*) was made up of a monochromatic camera (Hymatom) fitted with a 12 mm lens (Cosmicar). The fiber web was illuminated from the same side as the camera using a fluorescent lamp fixed to the side of the viewing box. To avoid producing reflections of the lamp on the glass window, a deflector system reflected the light onto the cotton. The reflecting devices employed did not distribute the light equally over the fiber web, and led to contrast variations in the image.

At this stage in the development process, improving the lighting quality would have required more investment than in any device currently available on the market.

We chose to use a scanner (Hewlett Packard Scanjet 4c) as this can acquire images under better lighting conditions. The principle of the scanner consists of passing a powerful, stable light connected to an acquisition device over the sample which is pressed against a glass plate. The device builds up an image of the sample line by line. The scanner's control program transfers the digitalized image into the computer's memory. This control program can also be used to vary acquisition resolution corresponding to the number of dots per inch (dpi, 1 inch = 25.4 mm) formed by the scanner to built the image. The resolution proposed ranges from 75 dpi (identical to the Hymatom camera) to 600 dpi. The time required to acquire the image is proportional to the resolution requested.

Tests were conducted at different image acquisition resolutions. By adjusting the algorithm to correspond to the resolution of the image formed, the defects detected and calculation time were always the same regardless of the resolution selected.

To reduce the time required to perform an analysis and improve the evaluation of SCF potential from cotton samples, we selected the optimum time/precision combination, i.e. analysis of images acquired by the scanner set at 100 dpi.

Adjustment of the Algorithm

The images acquired by the scanner were first analyzed by the algorithm set in camera mode. The results obtained were imprecise. The parameters contained within the algorithm therefore required specific adjustment.

An analysis of each imperfection in a set of 12 images was used to built specific procedures. To optimize these settings and correctly detect the defects encountered, 3 parameters set in the camera version of Trashcam V3 were also adjusted.

Results

First Comparison: Relationship Between 2 Visual Counts

A series of tests was conducted to verify these new settings on a set of 12 images taken of 14 cotton samples of various origins. This corresponded to a total of 166 cotton web images acquired by the scanner (2 images were discarded because of computer problems).

Figure 1 shows a comparison between 2 visual counts of the 166 images acquired. These images were displayed on the computer screen and dark patches were counted visually. The hypothesis was put forward that only the SCF remain on the fiber web after carding. In order to meet linear regression conditions (normal, independent variables and homogeneous variances) we used square root transformation of the counts obtained. All confidence intervals in this document were calculated with a type I risk of $\alpha = 5$ %.

The following were observed:

- a good correlation of 0.943 was obtained, with square root of visual2 count = 1.06 (±0.058) * square root of visual1 count + 0.408 (±0.34),
- the second count gave a result that was globally higher than the first: the "expert" being subjected to various error-producing phenomena during the count:

  ~ The experience acquired by the "expert" during successive counts of different images allowed him to better differentiate true SCF from spots corresponding to shadows. This error occurred less often with the scanned images than with the camera-acquired images.

  ~ As the lighting system was more appropriate, the contrast between SCF and background was improved. Visual fatigue was less pronounced with the scanner than when counts were performed on camera-acquired images.

~ However, cotton containing few SCF tended the “expert” to over-evaluate local contrasts which will be considered as SCF.

~ As image definition was improved, small impurities were more easily detected both by the "expert" counting the scanner-derived image and by the algorithm.

The visual counts showed good repeatability overall, but were subject to all the variability factors described above. Mean values obtained by these two counts were used as reference values to set the algorithm.

Second Comparison: Relationship Between Square Root of Mean Visual Count and Square Root of the Automatic Count

Figure 2 shows the relationship between the square root of the mean visual count (considered as the reference) and the square root of the count made by the Trashcam with parameters set using the original 12 images.

It was noted that the square root of the Trashcam count = 1.002 (±0.042) * square root of the visual count + 0.67 (±0.26) with a correlation of 0.965.

The acquisition equipment used and the adjusted algorithm settings markedly improved the slope between the square roots of the visual and automatic counts: this was improved from 0.76 (±0.029) using camera acquisition and Trashcam V2, then 0.867 (±0.024) with camera acquisition and Trashcam V3 (Giner *et al*, 1997), to a slope not different from 1 using the scanner and appropriate algorithm settings.

The Trashcam would seem to count too many black spots (y-intercept statistically different from 0). Counting error may be explained by one or several of the following:

- samples of cotton selected
- samples presented all the types of defect encountered routinely,
- all card webs were supposed to be prepared using an identical method,
- scanner settings (resolution, contrast, light intensity, etc) were the same for all the images,
- the "expert" count was under-estimated,
- eye-fatigue and adverse effects during visual counting,
- quality of the screen used for the visual count,
- the algorithm over-estimated the count,
- interaction between parameter settings and image quality.

The y-intercept deviation at the origin, on a normal counting scale (without square root transformation), corresponded to 0.43 SCF. This error is probably related to variations noted during visual counting. However, when the technique is used during varietal improvement programs, this error is negligible in comparison with the genetic variability and the sampling variability.

Conclusion

The Trashcam V3 interface was modified in order to use a scanner as a new method for acquiring images of card webs composed of cotton fibers. The apparatus used is made up of standard equipment available on the market. The assembly is less cumbersome and could receive support from the various manufacturers. It is nevertheless possible to continue analyzing images taken using the camera. In all cases Trashcam must be configurated with a set of parameters appropriate to the means used to acquire the images. Several series of algorithm-setting parameters are available: camera, scanner.

Our results show that visual counting of the same image is fairly repeatable whereas Trashcam counting is entirely repeatable. Under these conditions, Trashcam gives a similar count to the visual counting of an image on the computer screen. The slope of the regression line between these two variables is not different from 1. Although the y-intercept is slightly different from 0, this deviation is negligible when compared with the error risk encountered when analyzing SCF potential in plant lines derived from varietal improvement programs.

To simplify the method we have started research into the possibility of replacing the laboratory mini-card with a more rapid web-preparing device. This procedural change will doubtless modify the number of imperfections in the fiber web by adding other impurities such as leaves, barks, etc. The algorithm already has the possibility of detecting SCF without counting these other impurities.

By avoiding the requirement to manufacture yarn, Trashcam can exert selection pressure as regards SCF potential during varietal improvement programs. As new lines can be analyzed early, it is now possible to create varieties with reduced SCF content. The performance of textile machines will therefore be increased and yarn irregularities decreased.

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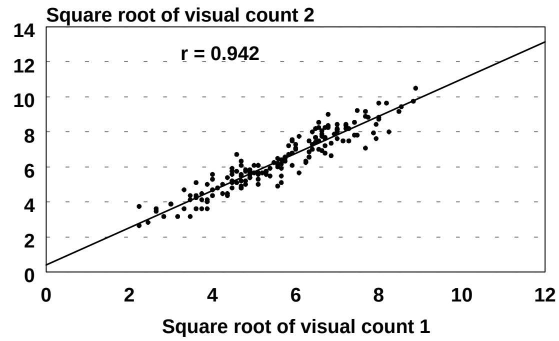

Figure 1: Relationship between square root values of 2 visual counts.

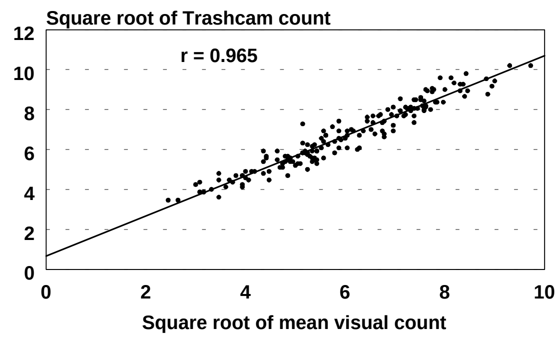

Figure 2: Relationship between the square root values of the automatic count and the square root values of the mean visual count made on scanner-acquired images.