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ENGINEERING AND GINNING

NOTE

A Preliminary Investigation into the Feasibility of Gin Blending

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ABSTRACT

The biggest discounts to the grower are for grade, length and micronaire. Since round modules do not blend cotton from multiple parts of a field as conventional modules did, some round modules may fall below base grade. This study was initiated as a preliminary evaluation to determine the effect of gin blending on fiber, yarn and fabric processing performance and quality and the potential economic return to the grower. One lot of irrigated and dryland stripper-harvested seed cotton, with different pre-determined micronaire and length properties, were blended together in four different ratios (80/20%, 60/40%, 40/60% and 20/80%) at the gin and at the textile mill. The resulting two cottons and four blends were carded, ring spun, knitted, scoured, bleached and dyed. Based on the 2016 CCC loan schedule, gin blending can benefit the grower with the biggest economic benefit, about $5 per bale, obtained from the 80/20 and 60/40 blend ratios when using seed cotton with these particular qualities from this one-year study. Processing performance and yarn and fabric quality of the gin blended product were not different from that of the unblended cotton and the mill blended fiber, indicating no serious consequences associated with gin blending, cotton with this micronaire and length range, to the spinner.

Cotton is currently grown in over 60 countries world-wide (Anon, 2016), with the blending of cotton lint from various parts of the world a standard practice for spinning mills, utilizing a number of different blending techniques. Fibers are generally blended before the carding process by laydown selection, tuft blending during the opening and cleaning process, the use of single or multiple blending chambers and blending during multiple drawing passages. The blending process starts with the selection of an appropriate number of bales from lots in the warehouse. Lots are generally segregated by consignments and quality parameters, and are chosen to ensure continuity of supply, avoid batch to batch variation, cost saving on raw materials, utilization of discount cotton and to produce special effects (Anon, 1972; Baker and Wanjura, 1976; Klein, 1987). The number of bales used in a bale laydown varies, and is very much dependent on the quality required and practical considerations, such as processing time per lot, floor space, production capabilities and the mixing power of downstream machines.

Blending has been a standard practice in spinning mills since the early 1800s (Baines, 1835) and minimal blending occurs during the harvesting and ginning process. The controlled blending of seed cotton prior to ginning is not common (Baker and Wanjura, 1976). Blending of seed cotton needs to be conducted prior to the ginning process as blending during the ginning process is impractical. A major reason for this is the equipment set up, with some gins able to produce a bale of cotton every minute, with most gins utilizing only a small reserve, both of which does not allow for any significant blending to take place. There are essentially three practical methods of blending seed cotton prior to ginning:

- Mix seed from different varieties in equal or varying amounts prior to planting.
- Sowing different varieties in an alternating row configuration, which are then harvested together.
- Feed different cotton qualities simultaneously into the gin (Baker and Wanjura, 1976; Bechere et al., 2008; Faircloth et al., 2003).

Several studies have been conducted to determine the potential of blending seed cotton from different varieties to maintain yield and improve fiber quality.

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Two preliminary studies were conducted in Lubbock, TX during 1971 and 1972, to determine the feasibility of blending two varieties that were stripper harvested. In the 1971 study, two varieties were fed simultaneously in equal proportions (50/50%) into a gin. The fiber and yarn results showed that those of the 50/50 blend fell between the results of the two varieties that were sown and processed independently. In the 1972 study, two varieties were both hand and gin blended, by either sowing two varieties in alternative rows in the field or by simultaneously feeding two varieties into a gin in blends of 75/25%, 50/50% and 25/75% respectively. The study showed that blending at the gin was more accurate than harvest blending and although there were some improvements in fiber quality, blending in either the field or at the gin did not result in an improvement in the grower's return (Baker and Wanjura, 1976). In a study (Faircloth et al., 2003) conducted in Clayton, NC from 1999 to 2001, it was found that, overall, there were no significant differences in fiber quality when mixing two varieties prior to sowing, or sowing the varieties in alternative rows. Another study (Bechere et al., 2008) conducted in 2001 and 2002 in Lubbock, TX, found that mixing the seed from two varieties prior to sowing in 75/25%, 50/50% and 25/75% blends improved the yield and fiber length, reduced length uniformity but had no effect on strength and elongation. Another study (Craig and Gwathmey, 2003, 2004) was conducted in Tennessee in 2002 and 2003 to determine whether fiber quality could be improved by mixing the seed from two varieties equally prior to sowing, and sowing the different varieties in alternate rows. The studies found that such blending did not have a significant effect on either fiber yield or quality. In another study (Dobbs et al., 2007), conducted from 2003 to 2005 in Stoneville and Verona, MS, it was found that mixing the seed from two varieties prior to sowing and sowing different varieties in alternate rows in different blends (75/25%, 50/50% and 25/75%) resulted in an increase in gin turn out and improved fiber length with only minor changes in fiber strength and uniformity. These improvements in fiber quality did not, however, improve the grower's income.

It is fair to say that all the previous studies have shown that fiber length, length uniformity, strength, and micronaire can be influenced by blending in the field, but that there is little, if any, economic benefit to the grower. Nevertheless, there is considerable interest within the cotton producing industry to blend at the gin. This could potentially be of benefit to both the grower and the textile mill. From a grower's perspective, blending at the gin provides an opportunity to avoid discounts, mainly for grade, length and micronaire, due to variable or damaged cotton. It also could reduce variability between round modules since round modules do not blend cotton from multiple parts of a field the way conventional modules did, the risk of inter-modular variation in fiber properties is greater with round modules (van der Sluijs et al., 2015). By blending seed cotton from modules during the ginning process, these discounts could possibly be avoided and ensure consistency of fiber quality. From a spinners perspective blending at the gin provides an opportunity to reduce variability and improve consistency of fiber quality which could lead to improved processing performance and yarn quality.

The introduction and rapid adoption of harvesters with on-board module building capacity is seen as an ideal opportunity to make blending prior to ginning a reality. Gins have been forced to make major changes to their operations to enable the processing of these modules, which has resulted in several gins that have the capability of feeding their gins with multiple modules (conventional and/or round) simultaneously. Although previous studies have shown that there is no significant economic return for a grower when blending seed from various varieties or sowing different varieties in an alternating row configuration, the effect of blending at the gin on fiber quality is not clear. Furthermore, few of the previous studies determined what effect blending prior to the spinning mill will have on textile processing performance and yarn and fabric quality. In this feasibility study, with no replication, we will examine what the economic benefits are to the grower and what effect gin blending has, in comparison to mill blending, on textile processing performance with quality validated on both yarn and fabric quality.

METHODS AND MATERIALS

In the present study, one trailer of approximately 300 kg of seed cotton, from irrigated and dryland cotton, were used to conduct small batch testing. Fiber quality data from an HVI™ and AFIS PRO instrument was used to determine the blending ratios and their effect on ginned quality. Quality was validated by small scale textile processing trials, conducted at the United States Department of Agriculture, Agricultural Research Service, Southern Regional Research Center (USDA-ARS-SRRC) Cotton Structure and Quality Research (CSQRU) Unit in New Orleans, LA, to compare gin and mill blended fiber in terms of mill processing performance and quality of yarn and fabric.

Seven different cottons were grown for this study in two fields, (four in an irrigated field, three in a dryland field) near the USDA-ARS Cotton Production & Processing Research Unit (CPPRU) in Lubbock, TX. The cotton was produced during the 2015/2016 growing season (planted; defoliated, harvested and ginned in 2015). A summary of the field operations employed is presented in Table 1. The fields were defoliated by applying 0.5 L/ha of CutOut™ from Nufarm using a ground rig. The irrigated field was harvested, according to normal industry practice and manufacturers recommendations, with a John Deere four row 7460 brush roll stripper, with field cleaner and the dryland field was harvested with the same harvester retrofitted with an eight-row wide header. In both instances, harvesting took place later in the day to ensure that harvested cotton did not have a surface moisture level greater than the recommended level of 12%. One trailer of each of the seven cottons was harvested and transported to the gin at CPPRU.

Selection of material for blending. Three bags of seed cotton each weighting 14 kg from each of the seven cottons were collected at random from each trailer and ginned on a 21 saw Continental research gin. Seed cotton was cleaned by an extractor-feeder prior to the gin stand and the lint was cleaned by one saw-type lint cleaner. Three fiber samples produced from each bag of seed cotton was collected and forwarded to CSQRU, for testing on an HVI model 1000 (Uster® Technologies Incorporated, Knoxville, TN). Five replicates of each sample were tested for color (reflectance Rd, and yellowness +b), trash count and percent trash area, upper half mean length (UHML) in mm, percent length uniformity (UI), short fiber index (SFI), bundle strength (g/tex) (Str), percent bundle elongation (El), and micronaire (Mic), as per ASTM D5867 (ASTM, 2012). Fiber samples were also subjected to analysis by the AFIS PRO instrument (Uster® Technologies Incorporated, Knoxville, TN). Three replicates, of 5000 fibers were tested from each sample to determine total and seed coat neps (SCN), trash and dust per gram, percent visible foreign matter (VFM), fineness (Fn) and maturity ratio (MR) as per ASTM D5866 (ASTM, 2012).

The average fiber quality was calculated for each of the seven cottons, the means for the HVI presented in Table 2. The AFIS PRO values appear in Table 3.

Table 1. Field size, planting, harvest aid application and harvest date

Field	Field size (ha)	Variety	Treatment	Planting date	Harvest Aid date	Harvest date	Amount Harvested (kg)
TAMU 407	1.1	DP1044 B2F	Irrigated	27 May	15 Oct	12 Nov	847
TAMU 407	1.1	ST4946 GLB2	Irrigated	27 May	15 Oct	12 Nov	871
TAMU 407	1.1	FM2484 B2F	Irrigated	27 May	15 Oct	12 Nov	674
TAMU 407	1.1	NG4111 RF	Irrigated	27 May	15 Oct	12 Nov	473
Liberty	3.3	FM9180 B2F	Dryland	19 Jun	15 Oct	19 Nov	3900
Liberty	3.6	NG4111 RF	Dryland	3 Jun	14 Oct	19 Nov	3366
Liberty	3.8	DP1044 B2F	Dryland	4 Jun	14 Oct	19 Nov	5225

Table 2. Mean HVI fiber properties based on five measurements

Variety	Treatment	+b	Rd	UHML mm	UI %	SFI %	Str g/tex	El %	Mic
DP 1044 B2F	Irrigated	7.1	75.9	29.72	83	8.5	31.5	9.5	4.4
ST 4946 GLB2	Irrigated	7.6	75.0	29.21	83	8.3	32.6	8.6	4.3
FM 2484 B2F	Irrigated	6.6	77.5	31.00	83	8.4	34.3	6.8	3.8
NG 4111 RF	Irrigated	8.1	74.5	29.21	83	7.9	33.5	8.3	4.4
FM 9180 B2F	Dryland	8.3	76.3	28.19	81	10.2	31.5	7.8	4.0
NG 4111 RF	Dryland	8.7	73.9	27.18	82	9.2	30.2	8.1	4.7
DP 1044 B2F	Dryland	8.0	75.4	28.19	82	9.6	30.4	8.9	4.4

+b -yellowness, Rd- reflectance, UHML- upper half mean length, UI- % length uniformity, SFI- short fiber index, Str- bundle strength, El- % bundle elongation, Mic- micronaire

By any measure, the quality of the fiber produced by both treatments (Irrigated & Dryland) can be considered as good for stripper harvested cotton. The average micronaire ranged from 3.8 to 4.7, which was within the base range of 3.5 to 4.9, UHML ranged from 27.18 mm to 31.00 mm, UI from 81 to 83 %, SFI from 5.4 to 9.3 %, bundle strength from 30.2 to 34.3 g/tex, and elongation from 6.8 to 9.3%. In terms of color, the Rd ranged from 73.9 to 77.4 units and the +b from 6.6 to 8.7 units. This translated into a color classing grade difference of 1 grade; 31 (Middling) and 41 (Strict Low Middling).

As expected, the irrigated fiber was on average longer, stronger, more uniform in length with fewer short fibers, and had higher elongation. The irrigated FM 2484 B2F cotton produced fiber with the best quality (finest, longest, and strongest). In contrast, the dryland NG 4111 RF cotton produced the coarsest, shortest and weakest fiber.

In terms of AFIS PRO measurements (Table 3), the average nep level ranged from 201 to 308 neps/gram, SCN from 9 to 15 neps/gram, dust content from 234 to 478 particles/gram, trash content from 74 to 160 particles/gram, and visible foreign matter from 1.28 to 2.75%. Fiber fineness ranged from 168 to 191 mtex and maturity ratio from 1.01 to 0.96.

There were no clear trends in terms of nep content, although the coarsest fiber (dryland NG 4111 RF) did produce the least number of neps and the (irrigated DP 1044 B2F) amongst the highest. Interestingly, the dryland cotton contained the least amount of dust and trash, resulting in lower percent visible foreign matter.

Based on the analysis of the seven cottons, two cottons were chosen, and a blend was made, prior to ginning and at the mill, using the cottons that exhibited the largest difference in micronaire, UHML, and strength values and have the most impact on bale price and return to the grower. To this end the NG 4111 RF dryland seed cotton from the Liberty field and the FM 2484 B2F irrigated seed cotton from the TAMU 407 field, were blended prior to ginning and at the mill in random order in four ratios as well as unblended, each 91 kg lots. This amount of cotton allowed for further fiber testing and ensured that there would be at least 23 kg of lint, necessary for processing the fiber into yarn on the small-scale processing line. Details of the various blend ratios are presented in Table 4.

The blends were made by weighing the amount of seed cotton needed and then blending the seed cotton with pitchforks prior to the seed cotton being conveyed into the gin - Figure 1.

Figure 1. Blending of seed cotton prior to ginning

Table 3. Mean AFIS PRO fiber properties based on three measurements

Variety	Treatment	Nep Cnt/g	SCN Cnt/g	Trash Cnt/g	Dust Cnt/g	VFM %	Fn mtex	MR
DP 1044 BSF	Irrigated	308	15	130	356	2.05	191	0.97
ST 4946 GLB2	Irrigated	254	14	163	460	2.46	183	0.99
FM 2484 B2F	Irrigated	295	15	164	478	2.75	168	0.99
NG 4111 RF	Irrigated	201	13	129	378	2.21	189	1.01
FM 9180 B2F	Dryland	270	12	127	363	1.99	169	0.96
NG 4111 RF	Dryland	222	9	74	234	1.28	189	1.01
DP 1044 B2F	Dryland	269	14	126	363	2.17	186	0.98

SCN- seed coat neps, Fn- fineness, MR-maturity ratio, VFM- % visible foreign matter.

Table 4. Varieties and blend ratios

Variety	Blend Ratio in %						Variety
FM 2484 B2F (Irrigated)	100	80/20	60/40	40/60	20/80	100	NG 4111 RF (Dryland)

All the cottons were ginned under standard commercial conditions using standard processing stages as recommended by the Cotton Ginners Handbook for stripper harvested Upland cotton (Baker, 1994). The pre-cleaning system consisted of a tower dryer, an inclined hot air cylinder cleaner, and a combination burr and stick machine. It was followed by a second tower dryer, a second inclined hot air cylinder cleaner, and a stick machine. The dryer burner controls were set to 93°C for the processing of all samples. Seed cotton was then fed by an extractor-feeder to the 93-saw Continental Double Eagle saw gin stand. The fiber was cleaned by one saw-type lint cleaner prior to baling.

One sample of seed was collected from the gin stand of the gin blended fiber, for each of the six gin blends (two unblended and four gin blended) and forwarded to Monsanto in Lubbock for residual lint and mechanical damage tests. Two replicates from each sample were tested for residual lint and visible mechanical damage. Residual lint was determined by acid delinting according to Monsanto's in-house test method. The total mechanical damage was assessed according to the method described by (Delouche, 1996).

Fiber samples from each of the 10 (two unblended and four gin and four mill blended) blends were collected at random and subjected to testing, as outlined previously.

The USDA small-scale processing plant was used to convert the fiber into 30/1 Ne carded ring-spun yarns with a twist factor of α_e 3.8. Fiber of the gin blended, and mill blended lots were processed on a 1 m wide opening/cleaning/carding line by American Truetzschler (Charlotte, NC). The opening line consisted of an opening hopper (Whitin Machine Works, Whitinsville, MA), Axi-Flo coarse opener, LVSA, GBRA fine opener, RN fine opener, RST fine cleaner, and Dustex dust removal system. The opened and cleaned cotton was then carded on a DK 803 carding machine at 45 kg/hr to produce a 70 gr/yd sliver. A mass balance to determine the percent waste through opening and carding was performed for each lot. Drawing was carried out through one pass on a Rieter RSB-951 and a Rieter SB-51 draw frame (Winterthur, CH) respectively. Roving was produced at one hank on a Zinser 660 roving frame (Sauer GmbH, Uebach-Palenburg, DE). Spinning was conducted on a Zinser 321 ring spinning frame, with 160 bobbins of yarn produced for each lot. Ends down were recorded during spinning to measure spinning efficiency. Single jersey knitted fabrics of approximately 160 g/m^2 were produced on a Lawson Hemphill FAK-S (Swansea, MA) sample knitting machine. Figure 2 provides the material flow and processing parameters from fiber to fabric.

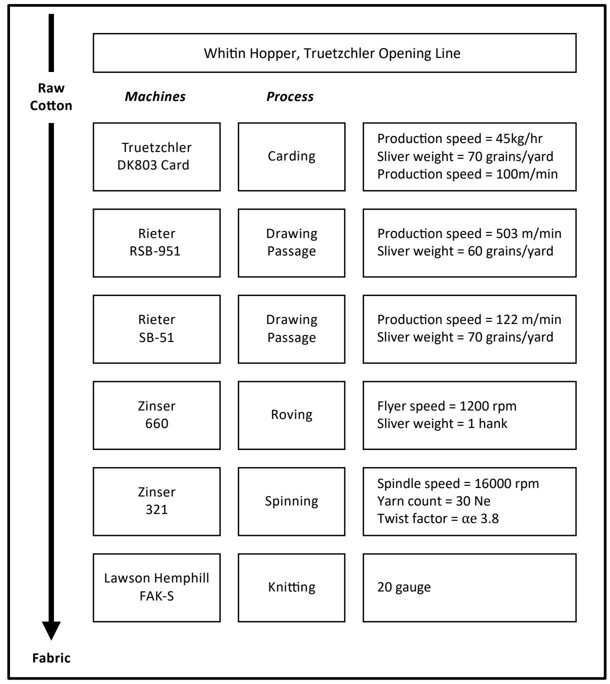

Figure 2. Textile processing for the production of fiber to fabric

Four knitted fabric samples were prepared for each lot. They were scoured and bleached together with one of the four samples being dyed separately. All wet processing was performed using a Mathis Lab Jumbo Jet JFO (Oberhasli, CH) overflow dye jig. Scouring was performed using Triton X-100 wetting agent at 0.25 g/l and 2.5 g/l sodium hydroxide at 100°C for 30 minutes, after which neutralization took place using 0.5 g/l acetic acid at 50°C for 15 minutes. Bleaching was performed using 50% peroxide bleach at 5g/l. The fabrics were dyed using Triton X-100 wetting agent at 0.25g/l and a reactive dye (Novacron Blue LS-3R, Hunstman International, The Woodlands, TX) at 1% concentration heated from 30°C to 90°C, at 1°C/min, and then held for 30 minutes at 90°C. The dyed fabrics were rinsed and neutralized using 1.0 g/l acetic acid. All ancillary chemicals were obtained from Sigma-Aldrich (St. Louis, MO) and used as provided.

Twenty spinning packages from each lot were tested for yarn strength and elongation utilizing an Uster® Technologies Tensorapid 4 (Uster, CH) with 20 breaks per package as per ASTM D2256 (ASTM, 2015). Yarn uniformity, imperfections (thin/thick/neps), and hairiness index were measured on an Uster® Technologies Tester 4 (Uster, CH), as per ASTM D1425 (ASTM, 2014). Fabrics were characterized prior to processing and after dyeing. Fabric color was measured in five locations per fabric using a Gretag Macbeth ColorEye 7000a (X-Rite Corporation, Grand Rapids, MI) instrument. The Delta E values were then calculated to indicate the differences in color between the fabrics and cotton A.

As this study was an initial evaluation, with no replication only descriptive statistics were produced. The average fiber, yarn and fabric qualities, as well as their processing performance, were calculated from the results of the two different cottons and blended fiber.

RESULTS AND DISCUSSION

Lint turn out

The two cottons performed as per the seed company data sheets and achieved a lint turn out between 32 and 37%. The lint turn out achieved for the two cottons used in this study were similar and are presented in Table 5. As the gin turn out for the two cottons were similar and due to the relatively small amount of seed cotton ginned, the gin turn out for the various blends was not measured.

Evaluation of the seed data is presented in Table 6. The average residual lint for the two varieties and the various blends was similar. The mechanical damage for the two cottons and blends was also similar and considered to be low. The low level of damaged seed was likely since the seed cotton was harvested during ideal conditions with a stripper that was maintained and operated via normal industry practice and manufacturer’s recommendations.

Fiber quality

Unblended. As highlighted earlier, the seed cotton from the cottons that exhibited the biggest difference in micronaire, UHML, and strength were chosen to process as 100% and in various blends as stipulated in Table 4. Table 7 and 8 show the HVI and AFIS PRO results for cottons A and C and their four gin and mill blends. As can be seen there were large differences in terms of micronaire, UHML, SFI, and strength. The extremely high strength result for the finer, irrigated, FM 2484 B2F fiber was likely because more fibers were present in the beard during strength testing. Although there was a difference in color in terms of Rd and +b values, there was only a slight difference in the average color grades for the two varieties, with the color grade for cotton A 41-1 and cotton C 41-3, which are both considered to be Strict Middling. As can be seen in Table 8, there were also differences in terms of fiber fineness and maturity. Finer (lower micronaire) cotton fibers form neps more easily than coarser fibers since the former are less rigid and therefore more easily bent, buckled, and entangled during mechanical handling.

Blended. There were no differences in terms of SFI, UI, and trash between cotton C and the gin and mill blended fiber results. However, there were large differences between the unblended and the gin and mill blended fiber results in terms of micronaire, UHML, strength, and elongation. Although there were differences in terms of the color (Rd and +b), there were no practical differences as the color grades at 41-1 were the same.

Table 5. Lint turn out and yield

Variety	Treatment	Cotton	Gin turn Out (%)	Seed Cotton Yield (kg/ha)	Lint Yield (kg/ha)
FM 2484 B2F	Irrigated	A	33.2	2986	986
NG 4111 RF	Dryland	C	34.4	1090	355

Table 6. Residual lint and mechanical damage

Variety	Treatment	Ratio	Residual lint (%)	Mechanical Damage (%)
FM 2484 B2F	Irrigated	A	12.5	7
NG 4111 RF	Dryland	C	12.8	5
		80A/20C	10.3	6
		60A/40C	10.3	6
		40A/60C	11.0	6
		20A/80C	11.0	6

Table 7. HVI determined fiber properties for unblended vs gin (G) and mill (M) blended

Ratio	+b	Rd	UHML mm	UI %	SFI %	Str g/tex	El %	Mic
A	6.7	78.7	31.00	81.9	8.2	35.14	6.6	3.77
C	8.8	74.1	27.18	81.8	8.7	31.04	6.8	4.70
G80A/20C	7.0	77.6	30.48	81.3	8.9	35.24	7.0	3.98
G60A/40C	7.6	76.7	29.21	81.5	8.6	33.38	7.2	4.10
G40A/60C	7.8	76.2	28.70	80.8	9.8	32.50	7.4	4.23
G20A/80C	8.4	74.8	28.19	81.0	9.0	33.08	7.8	4.44
M80A/20C	6.8	78.4	30.73	82.3	8.8	33.26	7.0	3.76
M60A/40C	7.5	76.2	29.00	80.5	9.4	31.36	7.7	4.18
M40A/60C	7.2	77.0	29.21	80.7	9.1	31.58	7.2	4.20
M20A/80C	6.8	78.0	30.48	82.0	8.3	33.42	7.1b	3.92

+b -yellowness, Rd- reflectance, UHML- upper half mean length, UI- % length uniformity, SFI- short fiber index, Str- bundle strength, El- % bundle elongation, Mic- micronaire,

Table 8. AFIS PRO and HVI determined fiber properties for unblended vs gin (G) and mill (M) blended.

Ratio	AFIS PRO							HVI		
	Nep Cnt/g	SCN Cnt/g	Fn mtex	MR	VFM %	Trash Cnt/g	Dust Cnt/g	Leaf	% Area	Trash Count
A	356	9	169	0.97	1.05	62	357	2.2	0.23	40
C	194	7	190	1.01	1.26	42	303	1.6	0.21	33
G80A/20C	305	7	165	0.96	1.22	62	422	2.2	0.24	40
G60A/40C	283	7	171	0.97	0.85	49	321	2.0	0.25	40
G40A/60C	257	6	171	0.97	0.90	61	347	1.8	0.18	30
G20A/80C	244	4	177	0.96	0.54	37	237	1.6	0.17	25
M80A/20C	363	6	169	0.97	1.15	63	394	2.8	0.29	44
M60A/40C	372	7	166	0.97	1.73	93	485	3.0	0.35	43
M40A/60C	195	9	192	1.00	1.00	51	289	2.8	0.29	48
M20A/80C	308	7	175	0.98	1.23	81	372	3.0	0.36	50

SCN- seed coat neps, Fn- fineness, MR-maturity ratio, VFM- % visible foreign matter.

With respect to HVI fiber properties, there were no differences between the 80/20 gin and mill blends for all the fiber properties, except for strength and to a lesser extent UI, with the gin blended fiber on average nearly 2 g/tex stronger than the mill blended fiber. There were, however, differences for the 60/40 gin and mill blends in terms of strength, elongation and trash. The strength for the gin blended fiber was on average 2 g/tex stronger with 6.5% less extension and with a lower leaf grade (2 to 3), percent area (0.25% to 0.35%), and trash count (40 to 43) than the mill blended fiber. There were also differences for the 40/60 gin and mill blends in terms of trash, with the gin blended fiber having on average a lower leaf grade (2 to 3), with 38% less trash area and lower trash count of 23 than the mill blended fiber. Although there was a large difference in the +b value, this was not practically an issue as the color grades at 41-1 remained the same. Similarly, there were also differences for the 20/80 gin and mill blends for most of the fiber properties, except for strength and SFI. The micronaire for the gin blended fiber was 0.5 unit coarser, 2.29 mm shorter, with better uniformity index and a lower trash count of 25, which is half the amount of the mill blended fiber.

There were also differences with the AFIS PRO fiber properties, between the various gin and mill blends for all the fiber properties except for total nep and seed-coat neps. As with the HVI fiber properties, there were no differences for the 80/20 gin and mill blends for all the fiber properties. There were however, considerable differences for the 60/40 gin and mill blends in terms of trash, with the gin blended fiber containing on average 138 fewer dust and 32 fewer trash particles per gram, resulting in a lower VFM of 0.83%. This was not unexpected as the HVI trash values showed a similar trend. There were no differences for the 40/60 gin and mill blends, except for fineness with the gin blended fiber on average 21 mtex finer but still mature, when compared to the mill blended fiber. There were also no differences for the 20/80 gin and mill blends except for trash, with the gin blended fiber containing fewer dust and trash particles, resulting in a lower VFM% when compared to the mill blended fiber.

Economic considerations

It is important to determine what the gain from a grower's perspective would be in blending the two varieties. The fiber properties of the two varieties and their various blends were used to determine bale values using the 2016 Commodity Credit Corporation (CCC) Loan Schedule of Premiums and Discounts for Upland Cotton. The average loan rate ($US/lb) was calculated using micronaire, length, uniformity, strength and color grade from the five HVI test replicates. Loan rate and blend code were used to calculate the value of a bale of each single cotton or blend. A rudimentary analysis of the prices that would have been achieved for the two varieties and their respective blends using the Upland Loan Rate is presented in Table 9.

In terms of the unblended fiber, the irrigated FM 2484 B2F (A) achieved the highest price at US $266.16/bale and the dryland NG 4111RF (C) at US $256.08/bale. The study showed that blending seed cotton with this particular quality, the grower would benefit economically by blending cotton A with C, with the 80A/20C and 60A/40C yielding the highest price per bale in comparison to cotton C. An in-depth economic analysis considering different production scenarios, including cotton left over after blending, is needed to fully understand the economic implications of gin blending seed cotton.

Yarn processing performance

Textile mills are focused on process efficiency (output vs. input), and, therefore, many mills install elaborate systems to capture and accurately record waste figures from the various processes. To determine whether production levels and quality standards could be achieved, end breakages were recorded during the spinning process.

Unblended. Table 10 shows the percent waste and ends down for the two cottons and their gin and mill blends. The amount of fiber loss/waste extracted from cotton C was much higher, at 27%. As there were no differences in terms of trash in the fiber from the two cottons, the difference between cottons A and C are likely because the fiber from cotton C was coarser and shorter, the later probably explaining the higher waste. The number of ends down during the spinning process for cotton C were higher than cotton A.

Table 9. Loan discount/premiums for HVI grades from the 2016 Upland CCC Loan Chart

Ratio	Mic	Strength	UI%	Length/Color	Total [1,2]
A	15	45	5	280.0	$266.16
C	0	30	1.67	103.3	$256.08
G80A/20C	15	45	0	277.5	$265.82
G60A/40C	15	43	1	268.0	$265.30
G40A/60C	9	42	-18	282.0	$264.72
G20A/80C	0	43	-15	260.0	$263.42

[1] = US$/480 lb bale

[2] = Loan price calculation example for blend code A: $55.45 = (5200 + 15 + 45 + 5 + 280)/100. Base loan rate is 52.00 cents/lb. or US$249.60 per bale

Table 10. Mill processing data

Ratio	Opening/Card Loss (%)	Ends Down (/1000hr)
A	19.8	96.9
C	27.0	171.9
G80A/20C	25.3	43.8
G60A/40C	22.3	29.2
G40A/60C	23.0	43.8
G20A/80C	20.2	64.6
M80A/20C	27.7	44.4
M60A/40C	27.4	11.5
M40A/60C	20.7	28.1
M20A/80C	22.6	93.8

Blended. In terms of the gin blended fiber, there was a slight decrease in the percent card loss as cotton C was blended with cotton A. Surprisingly, there were much fewer ends down with the blends than for the unblended fiber from cotton A and C, even though C was both coarser and shorter than A. Overall, the best processing, in terms of card loss and ends down, was achieved with the G60A/40C blended fiber. In comparing the gin blended fiber the mill blend, there was a larger increase in the percent waste of the mill blend, as cotton C was blended with 20 and 40% of cotton A, with a reduction in the percent waste when cotton C was further increased to 60 and 80%. The ends down were variable across the range of blends but did trend similarly as the gin blended fiber. Overall the best processing performance in terms of card loss and ends down was achieved with the M40A/60C blended fiber. This blend performed slightly better than the best gin blended fiber (G60A/40C).

Yarn quality

Unblended. Table 11 presents the yarn results for the cottons A and C and their four gin and mill blends. In order to spin medium staple cotton into an acceptable quality ring-spun, yarn a spinner needs at least 80 fibers in the yarn cross section, with the number of fibers in the yarn cross section calculated as follows (McCreight, Feil, et al., 1997):

$$\text{Number of fibers} = \frac{\text{Yarn count in Tex (grams/1000 meters) x 25.4}}{\text{Micronaire of fiber}}$$

At 135 and 108 fibers in the yarn cross section respectively, varieties A and C, exceeded this minimum number of fibers for an acceptable 30/1 Ne ring-spun carded yarn.

There were considerable differences, in the yarn quality from cottons A and C, in terms of yarn strength and the number of imperfections in terms of neps and thin places. Since the yarn produced from cotton A contained more fibers in the yarn cross section (due to lower micronaire value) and the fact that the fibers were longer and stronger it was anticipated that the yarn produced would be of higher quality than the yarns produced from cotton C. However, while the yarn from cotton A was in fact the strongest (17.8 cN/tex), it was also the most uneven yarn, with more thick places and neps and the highest CV%. The higher number of thick places and neps were likely due to the fact that the fibers were finer and more flexible and could be more easily bent, buckled and entangled during mechanical manipulation (as noted in the number of neps in the ginned lint as measured by the AFIS PRO).

Blended. There were differences between the various gin and mill blends for evenness, imperfections in terms of thin and thick places per km and strength. There were no large differences for the 80/20 gin and mill blended yarn properties. There were however large differences for the 60/40 gin and mill blended yarns in terms of evenness, strength and the number of thick places. The strength of the mill blended yarn was on average 0.76 cN/tex stronger, more even, with 75 less thick places than the gin blended yarn. There were also large differences for the 40/60 gin and mill blended yarns in terms of evenness, strength and the number

Table 11. Yarn results for Unblended vs gin (G) and mill (M) blended

Ratio	CV %	Thick (+50)	Thin (-50)	Neps (+200)	H	Ten cN/tex	El %	CV% El	CV% Ten
A	18.9	843	73	245	5.7	17.8	5.2	6.6	7.8
C	18.5	689	89	153	5.8	15.0	5.0	7.5	8.8
G80A/20C	18.2	667	57	171	5.6	17.3	5.0	7.3	8.1
G60A/40C	18.6	734	76	180	5.7	16.3	4.9	7.5	7.8
G40A/60C	18.6	733	70	164	5.7	15.9	5.0	7.1	8.3
G20A/80C	19.1	810	105	163	5.9	15.5	5.0	8.3	8.8
M80A/20C	18.4	724	58	188	5.8	17.2	5.2	6.6	7.9
M60A/40C	18.2	659	59	177	5.7	17.1	5.1	7.4	7.7
M40A/60C	17.8	573	50	154	6.1	17.0	5.1	7.0	7.7
M20A/80C	18.4	681	78	164	5.8	16.0	5.1	7.4	7.8

CV% - evenness, Thick (+50) – thick places/1000 m, Thin (-50) – thin places/1000 m, Neps (+200) – neps per 1000 m, H – hairiness, Ten – Tenacity in cN/tex, El - % elongation, CV% El – variation in elongation, CV% Ten - variation in strength.

of thin and thick places. The strength of the mill blended yarn was 1.09 cN/tex stronger, with 0.4 percentage point lower CV%, with 20 fewer thin places and 160 fewer thick places than the gin blended yarn. Similarly, there were also large differences for the 20/80 gin and mill blended yarns in terms of evenness, strength and the number of thin and thick places. The strength of the mill blended yarn was 0.48 cN/tex stronger, with 0.8 percentage point lower CV%, fewer imperfections with 27 fewer thin places and 129 fewer thick places than the gin blended yarn.

Fabric quality

There were no differences in the average weight of the two varieties and their respective gin and mill blends. The average fabric weight for the dyed fabric from cotton A was 173 gm/m^2 and for cotton C 162 gm/m^2, with the fabric weights for the blended fiber ranging from 154 to 168 gm/m^2.

As mentioned previously, the color of the fabrics was measured using a laboratory grade spectrophotometer, which measures color based on the CIELab color model. The CIELab model reports color in terms of lightness when comparing (L*), white to black, (a*) redness to greenness and (b*) blueness to yellowness.

The average color difference, designated as Delta E, was calculated, using the CIE76 formula, (equation 1) to determine the color differences between the two varieties and the gin and mill blended fiber for the fabrics from the greige (fabric produced from yarn without any further processing) and the dyed processing stage. The higher the Delta E, the larger the variation between the color values.

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2} \qquad (1)$$

Unblended. The average Delta E values calculated using equation 1 and shown in Figure 3, for the greige fabrics produced from varieties A and C was 3.6. It is universally accepted that a Delta E value between 2.0 and 3.5 is considered a medium difference which is noticeable to the untrained eye and that a Delta E value between 1.0 and 2.0 is considered a small difference which is only just noticeable to the trained eye (Mokrycki and Tatol, 2011). These differences between the two greige fabrics was not entirely unexpected as the Rd and +b values for the fiber was also different.

The Delta E, for the dyed fabrics produced from A and C was 1.7, this color difference being barely noticeable to the trained eye. This was not unexpected as the scouring and bleaching process, prior to dyeing, is often able to reduce, or even eliminate, color differences present in raw cotton.

Blended. In terms of the gin blended fiber, the average Delta E values, for the greige fabrics produced from cotton A and blend G80A/20C was 1.0, for A and G60A/40C was 1.5, for A and G40A/60C was 2.2 and for A and G20A/80C was 2.8. These differences between A and the four blends became more noticeable to the trained eye, as indicated by the Delta E values, as the percentage of C was increased. The average Delta E values, for the dyed fabrics produced from cotton A and blend G80A/20C was 1.8, for A and G60A/40C was 1.3, for A and G40A/60C was 1.4 and for A and G20A/80C was 2.0. All these color differences would be only noticeable to the trained eye.

In terms of the mill blended fiber, the average Delta E values, for the greige fabrics produced from cotton A and blend M80A/20C was 1.1, for A and M60A/40C was 1.8, for A and M40A/60C was 2.7 and for A and M20A/80C was 3.7. The differences between A and the four mill blends became more noticeable to the naked eye, as indicated by the Delta E values, as the percentage of C was increased. The average Delta E values, for the dyed fabrics produced from cotton A and blend M80A/20C was 1.0, for A and M60A/40C was 1.4, for A and M40A/60C was 0.8 and for A and M20A/80C was 2.2. All these color differences are considered as small and would only be noticeable to the trained eye. Figure 3 shows the average Delta E values for the greige and dyed fabrics for cottons A and C and the differences between cotton A and the four gin and mill blends. The horizontal bars represent the 1, 2 and 3.5 Delta E differences.

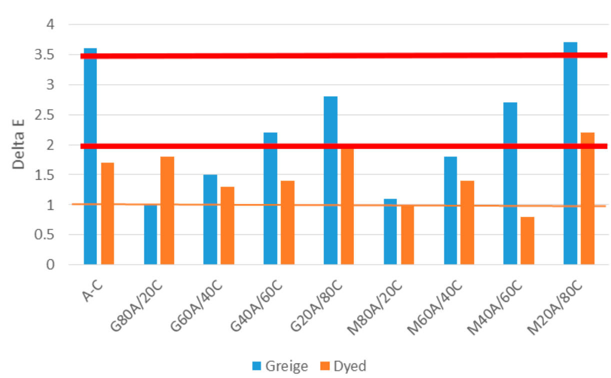

Figure 3. Delta E values for Unblended and gin and mill blended greige and dyed fabrics

CONCLUSIONS

There is considerable interest within the cotton producing industry to blend seed cotton at the gin for the benefit of both the grower and the textile mill. From a grower's perspective, blending at the gin provides an opportunity to avoid discounts. From a spinner's perspective, blending at the gin could provide an opportunity to reduce variability. Although previous studies have shown that there were no economic returns for a grower when blending seed from various varieties or sowing different varieties in an alternating row configuration, the effect of blending at the gin on fiber quality was not clear. Furthermore, few of the previous studies determined what effect blending prior to the spinning mill had on textile processing performance and yarn and fabric qualities. This preliminary study was initiated to determine the effect of gin blending on fiber, yarn, and fabric processing performance and quality and the potential economic return to the grower.

As the biggest discounts are mainly for grade, length, and micronaire, seed cotton with varying micronaire and length properties were blended at the gin and the mill in four different ratios (80/20%, 60/40%, 40/60% and 20/80%). This was done to determine whether there would be an economic advantage to the grower and what the consequence of gin blending would be on processing performance and product quality during textile processing. Gin blending benefitted the grower by as much as US $5.32 per bale, in this one-year trial without replications, without considering fiber left over after blending and any extra costs that the gin might incur. The biggest economic benefit, when blending seed cotton with these specific qualities, was obtained with the 80/20 and 60/40 blend ratios. This economic benefit was mainly because blending at the gin had a noticeable effect on micronaire and fiber length - both of which play a major part in determining the value of cotton lint. These results were obtained using seed cotton as described in this paper. Results from blending seed cottons having different fiber properties could yield different results.

In terms of fiber quality, the gin blended fiber was superior to the mill blended fiber. There were no large differences for the 80/20 gin and mill blended yarn properties, but the 60/40, 40/60 and 20/80 mill blends produced considerably superior yarns in terms of evenness, imperfections and strength.

There were also no major differences in processing performance between the two blending methods, and although there were color differences between the gin and mill blended fabrics, they were considered small and only noticeable to the trained eye.

This preliminary study has shown that the overall processing performance and yarn and fabric quality of the gin blended product was seldom different from that of the superior quality cotton, indicating no serious consequence to the spinner. Hence results from this study indicate the grower could benefit financially without adversely impacting the spinners with processing and quality issues. Furthermore, as a mill will blend a number of bales (10-90+), the blending effect would be even more intensive and hence with less chance of negatively influencing the processing performance and quality.

However, despite the benefits, a word of caution is necessary. Firstly, this study was conducted on a small scale, with no replication, where variables can be closely monitored and although the two varieties that were blended had different fiber properties, they both were still within the CCC Loan Schedule. Secondly, the fiber properties of the varieties were known prior to blending by conducting small scale ginning and fiber testing. Blending varieties which are more variable may improve the economic return to the grower but may result in processing performance and quality issues during textile processing which could damage the reputation of the growth and country of origin. Furthermore, blending varieties with different lint turn out can result in different blend ratios than originally intended. It is also clear that to achieve intimate and accurate blending, that a gin would need to install multiple module feeders.

Thus, it is the recommendation of the authors that a more in-depth study with multiple replications need to be conducted to see if the results in this study are repeatable and reliable.

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