HARVEST TIMING AND TECHNIQUES TO OPTIMIZE FIBER QUALITY – INITIAL FINDINGS

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Abstract

Production conditions typical to the Texas High Plains region can produce cotton crops with high short fiber and nep content, both of which have a detrimental impact on ring spinning performance. Since Texas now produces nearly 50% of the US cotton crop annually, it is critical that research focuses on finding ways to maximize fiber quality in order to improve the competitiveness of US cotton on the world market. The objectives of this work are to:

- Document the within-plant distribution of yield, fiber quality, and value for a well irrigated High Plains cotton crop,
- Investigate differences in fiber quality from cotton harvested with conventional equipment applied at different levels of final crop maturity, and
- Evaluate the economic feasibility of using new techniques with conventional harvesting equipment to maximize fiber quality.

Four harvesting treatments were investigated in this work: 1) picker harvest at 80% open bolls followed by a second picker harvest once all bolls were open, 2) picker harvest at 80% open bolls followed by a subsequent stripper harvest once all bolls were open, 3) conventional picking, and 4) conventional stripping. The findings of this work indicate that non-color fiber quality parameters can be improved through using a spindle picker at approximately 80% open bolls prior to defoliation. Lint value was decreased for these treatments due to poor color grades resulting from the presence of green leaf trash with high moisture content. A basic economic comparison of harvesting treatments indicated the highest net return for conventional picking but no significant difference was observed between conventional picking, conventional stripping, or the treatment using the picker at 80% open bolls prior to defoliation and then again once 100% open bolls were achieved. The harvest treatment using a picker at 80% open bolls prior to defoliation and then a brush-roll stripper at 100% open bolls after crop desiccation returned the lowest net value and was significantly lower than the conventional pick treatment.

Introduction

Cotton produced in the Texas High Plains has exhibited substantial improvements in terms of yield and fiber quality over the last decade. These improvements are due primarily to new cultivars, improved irrigation practices, and utilization of harvest-aid chemical products. However, cotton produced in the region continues to receive larger price discounts from buyers compared to cotton of equal grade and classification produced in other areas of the US. Foreign mills attribute inferior ring spinning performance of west Texas cotton to increased levels of neps and short fibers, both of which are not reported in fiber testing results from the USDA Agricultural Marketing Service using the high volume instrument (HVI) classification system.

The amount of neps and short fiber contained in ginned lint is influenced by many factors including: variety, fiber maturity, harvest-aid product and timing, harvest method, and ginning practice. Inclement weather, periods of excessive soil moisture from rainfall or irrigation, and limited heat unit accumulation (< 2500 DD60's) are production conditions experienced on the High Plains that tend to produce immature fiber with low micronaire (MIC). Cotton harvest on the High Plains is traditionally accomplished using brush-roll strippers that indiscriminately harvest seed cotton from bolls regardless of physiological maturity. Consequently, MIC for stripper harvested cotton has been shown to be reduced by 0.3 units compared to spindle picker harvested cotton of the same variety (Faulkner et al., 2009). Spindle pickers employ a selective harvesting mechanism which harvests seed cotton only from open bolls, leaving seed cotton in less-open/less mature bolls. Moreover, aggressive ginning practices that expose seed cotton to excessive mechanical action tend to break fibers and cause fiber entanglements (i.e. neps) (Anthony et al., 1986).

Fiber quality has been shown to vary by field location, boll location on the plant, and location on the seed (Ge et al., 2008; Johnson et al., 1998; Bednarz et al., 2007; Bradow et al., 1997; Bradow and Davidonis, 2000). Naturally, fiber quality and maturity increases for older bolls found at inside fruiting positions on branches located lower on the main stem. These findings support the idea that it may be possible to develop methods or technology that harvest cotton by position resulting in fiber segregation by quality. However, market conditions continue to reward producers for total production more so than quality. To that end, new harvesting methods must maximize the amount of total production gathered from the field in order to maximize producer returns.

The goal of this work is to improve fiber quality and value of cotton produced in the Texas High Plains through new harvesting techniques utilizing conventional harvesting equipment applied at various stages of final crop maturity. The specific objectives are:

- Quantify the within-plant distribution of yield, quality, and value for a well irrigated High Plains cotton crop,
- Investigate differences in fiber quality and maturity of cotton harvested using conventional equipment (e.g. a spindle picker and a brush-roll stripper with field cleaner) at different levels of final crop maturity, and
- Evaluate the economic feasibility of using these new harvesting techniques on irrigated High Plains cotton.

Materials and Methods

One variety of cotton, FiberMax 9180 B2F, was grown in a sub-surface drip irrigated field at the USDA - ARS Plant Stress Lab in Lubbock, TX. The crop was planted May 6, 2009 on rows spaced 40 in apart with drip lines under each row. A seeding rate of 5 seed/row-ft (65,000 seed/acre) was used and subsequent plant stand counts indicated an average population of 4 plants/row-ft (55,500 plants/acre). The field was divided into sixteen plots each six rows wide and approximately 540 ft long (~0.25 acres/plot). Soil sampling was conducted in each plot prior to planting to a depth of 24 in to determine residual fertility levels. Test results indicated an average of 28.4 lb NO_3-N/acre remaining in the soil across all plots. Accounting for residual N, approximately 175 lb-N/acre was applied through the irrigation system for a yield goal of 4 bales/acre (Lemon et al., 2009). No supplemental phosphorous, potassium, or trace minerals were applied. Early season irrigation was conducted by an automated irrigation controller at a rate of 0.2 acre-in/day. However, cut-out (defined as < 4 nodes above white flower) was observed earlier than expected on July 28, 2009 due to heat stress and daily irrigation was increased to 0.31 acre-in/day to help retain fruit load. Total irrigation amount was 17.5 acre-in with an additional 5.9 acre-in from rainfall.

Harvesting treatments evaluated in the study consisted of applying a conventional six-row cotton picker (John Deere model 9996) and a conventional six-row brush-roll stripper with field cleaner (John Deere model 7445) in various sequences at different levels of final crop maturity. Treatments included:

1. Pick then Pick: Picker harvest (~80% open bolls) prior to application of crop harvest-aid chemicals followed by a second picking (~100% open bolls) after crop defoliation,
2. Pick then Strip: Picker harvest (~80% open bolls) prior to application of crop harvest-aid chemicals followed by stripper harvesting (~100% open bolls) after defoliation and desiccation,
3. Conventional Pick: Once over picker harvest (~100% open bolls) after crop defoliation, and
4. Conventional Strip: Once over stripper harvest (~100% open bolls) after crop defoliation and desiccation.

Finish 6 Pro and Ginstar were applied at 24 oz/acre and 8 oz/acre, respectively over all plots to defoliate the crop and open bolls the day after the initial picking event for the Pick then Pick and Pick then Strip treatments. The day after the second picking event for the Pick then Pick treatment and once over picking for the Conventional Pick treatment, Gramoxone Inteon was applied at 32 oz/acre to the remaining plots to desiccate the crop for stripper harvesting. The timeline of events during the 2009 harvest season is shown in table 1.

The field was sub-divided into four blocks to which each treatment was randomly applied once (table 2). The blocks, serving as replications, each contained four plots (24 rows/block). Statistical analyses were performed according to a randomized complete block design with field replicates serving as blocks. Statistical analysis was conducted using the general linear model in SAS (SAS v. 9.1, SAS Institute, Cary, NC).

Prior to machine harvest for the first and second harvest events, box mapping was conducted on 100 plants from each field replicate according to the procedure described by McCarty et al. (1975). Before the initial harvest event, 50 plants were collected from the two plots per replicate to be harvested with the picker whereas 100 plants were collected from each of the four plots to be harvested under the conventional pick treatment prior to the second harvest event. The crop had an average of 81.3% open bolls prior to the first harvest event and 100% open bolls prior to the second harvest event. The process used to box map the plant samples consisted of hand harvesting each open boll individually from the plant and placing it in a specially made box that maintained the separation of bolls by fruiting position. The box (figure 1) was constructed with internal dividers that created individual spaces indexed by main-stem node number and boll position on the fruiting branch. All bolls harvested from vegetative branches were grouped together. The number of bolls harvested from each fruiting position was recorded and seed cotton weight was measured and recorded once the boll samples were hand de-burred. These data were collected to provide information on the within-plant distribution of yield and quality for the crop at approximately 80% and 100% open bolls. Ginning of the samples by fruiting position is in progress.

Table 1. Timeline for field activities conducted during the 2009 harvest.

Date	Event	Operation
9/21/09	Box Map 1	Box mapping of plots prior to initial picker harvest, 80% open bolls
9/22/09	1st Harvest Event	Initial picker harvest for Pick then Pick and Pick then Strip treatments
9/23/09	Defoliation	Finish 6 Pro and Ginstar applied to all plots
10/14/09	Box Map 2	Box mapping of conventional picking plots, 100% open bolls
10/15/09	2nd Harvest Event	Second picker harvest for Pick then Pick treatment and once over harvest for Conventional Pick treatment
10/16/09	Desiccation	Gramoxone Inteon applied to plots to be stripper harvested
11/3/09	3rd Harvest Event	Stripper harvest for Pick then Strip and Conventional Strip treatments

Table 2. Field layout and treatment assignments.

Rep #	Treatment Assignment	Plot #
Rep 1	Treatment #3 - Conventional Pick	1
	Treatment #4 - Conventional Strip	2
	Treatment #1 - Pick then Pick	3
	Treatment #2 - Pick then Strip	4
Rep 2	Treatment #2 - Pick then Strip	5
	Treatment #4 - Conventional Strip	6
	Treatment #3 - Conventional Pick	7
	Treatment #1 - Pick then Pick	8
Rep 3	Treatment #2 - Pick then Strip	9
	Treatment #3 - Conventional Pick	10
	Treatment #1 - Pick then Pick	11
	Treatment #4 - Conventional Strip	12
Rep 4	Treatment #2 - Pick then Strip	13
	Treatment #1 - Pick then Pick	14
	Treatment #4 - Conventional Strip	15
	Treatment #3 - Conventional Pick	16

Figure 1. Box constructed to facilitate box-mapping of plant samples.

Prior to machine harvest, seed cotton samples were hand harvested for gravimetric moisture content analysis and measurements were conducted in each plot to determine the harvesting efficiency of the machine. For each harvesting efficiency measurement, two 10 ft sections of a single row separated by a 5 ft buffer were marked off at a random distance in the field. For the first 10 ft row section (as would be encountered by the machine), the two row middles were swept clear of fallen seed cotton and plant material. The seed cotton from the second 10 ft row section was hand harvested. The seed cotton left on the plants and that forced to the ground by the harvester on one side of the first 10 ft row section were gathered and weighed. Harvesting efficiency was calculated according to equation 1.

$$E_H = 100 \times \left(1 - \frac{P+G}{H}\right) \quad (1)$$

where:

E_H = harvesting efficiency for the picker or stripper (%),
P = weight of seed cotton left on plants after machine harvest (g),
G = weight of seed cotton gleaned from the ground after machine harvest (g), and
H = weight of seed cotton hand harvested from plants in second 10 ft section of row (g).

After each plot was machine harvested, the burr-cotton was weighed and a 250 lb sample was collected for ginning at the USDA – ARS Cotton Production and Processing Research Unit in Lubbock, TX. Each burr-cotton sample was weighed and processed through commercial scale ginning equipment according to the following machine sequence: suction, green boll/rock trap, steady-flow feed control, first stage tower drier, first stage inclined cleaner, first stage extractor (combination burr/stick machine), second stage tower drier, second stage inclined cleaner, second stage extractor (stick machine), extractor-feeder, 93-saw gin stand, and two stages of saw-type lint cleaning. Heated air was used in the ginning process to dry the seed cotton harvested during all three harvest events but was especially needed after harvest event one to help remove large green leaf material with high moisture content. Seed cotton samples were collected at the suction telescope and feeder apron for gravimetric moisture content analysis and fractionation analysis according to Shepherd (1972). The weight of trash removed by the seed cotton cleaning machines and both lint cleaners was recorded for one sample from each treatment during ginning and photographs were taken to document the physical makeup of the material rejected by each machine. Lint samples were collected after the second stage lint cleaner and sent for HVI and advanced fiber information system (AFIS) fiber analysis at the Fiber and Biopolymer Research Institute in Lubbock, TX. Commodity Credit Corporation (CCC) loan values for the fiber samples were calculated according to the 2009 loan chart (USDA, 2009) using HVI fiber classification results. Total lint and seed weights were recorded for each sample and used to calculate lint and seed turnout values.

Results and Discussion

Seed cotton yield distributions for field replicate four from harvest events one and two are presented in figures 2 and 3, respectively. The distribution data from harvest event one (figure 2) indicate that approximately 95% of the crop was located below main stem node 14 when the crop had 79.5% open bolls. When the crop had 100% open bolls at harvest event two, approximately 82% of the crop was located below main stem node 14. The 20% additional crop yield observed for harvest event 2 was primarily due to the opening of bolls found at node 14 and above. First position bolls accounted for 78.6 and 78.5% of the crop yield for harvest events one and two, respectively while second position bolls contained 13.2 and 14.4%, respectively. Vegetative bolls contained approximately 7.9 and 7.1% of the crop yield for harvest events one and two, respectively. Third position bolls accounted for approximately 0.3% of the crop yield at harvest event one and 0% for harvest event two. Similar data were observed for all four field replicates. Additional quality and value distribution data are being analyzed.

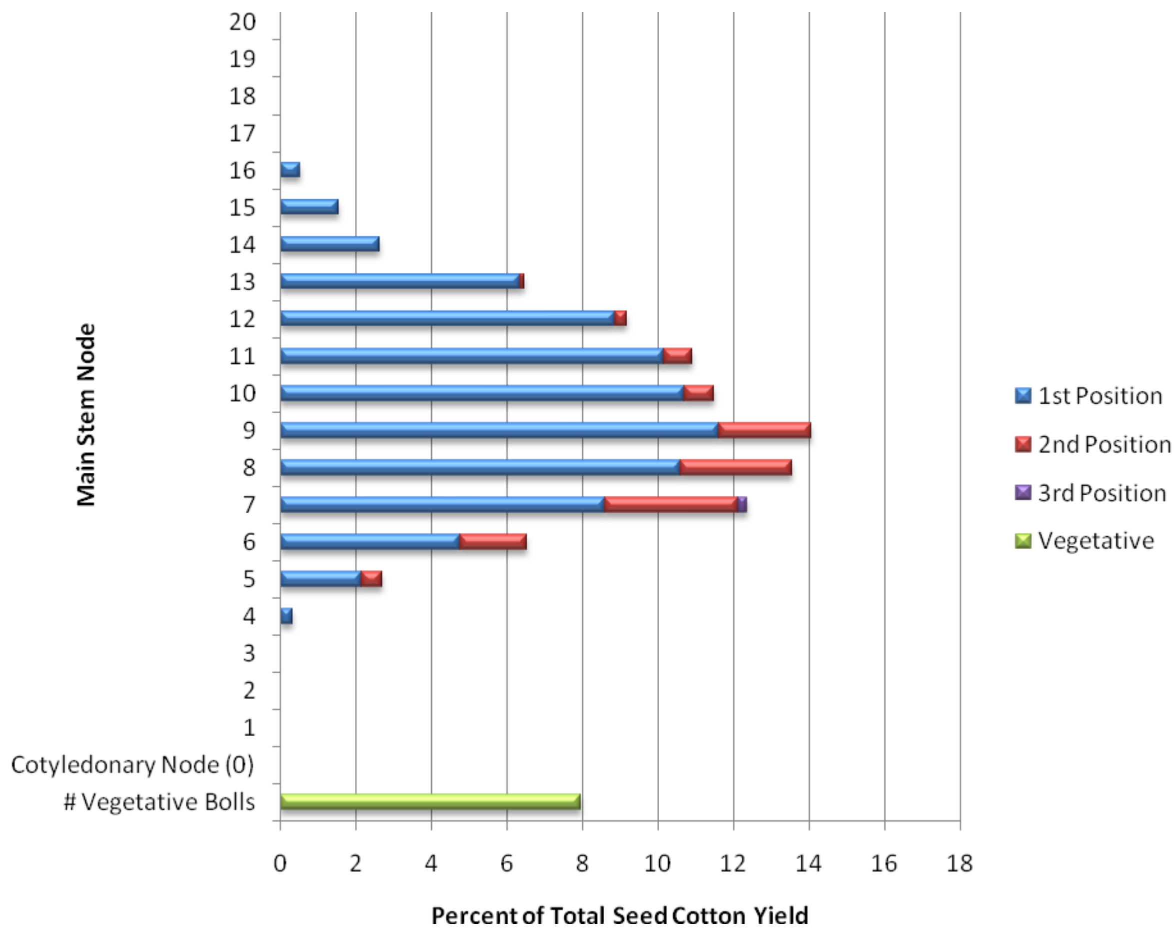

Figure 2. Harvest event 1 distribution of seed cotton yield by main stem node and fruiting position for field rep 4 (data from plots 13 and 14 combined, 79.5% open bolls).

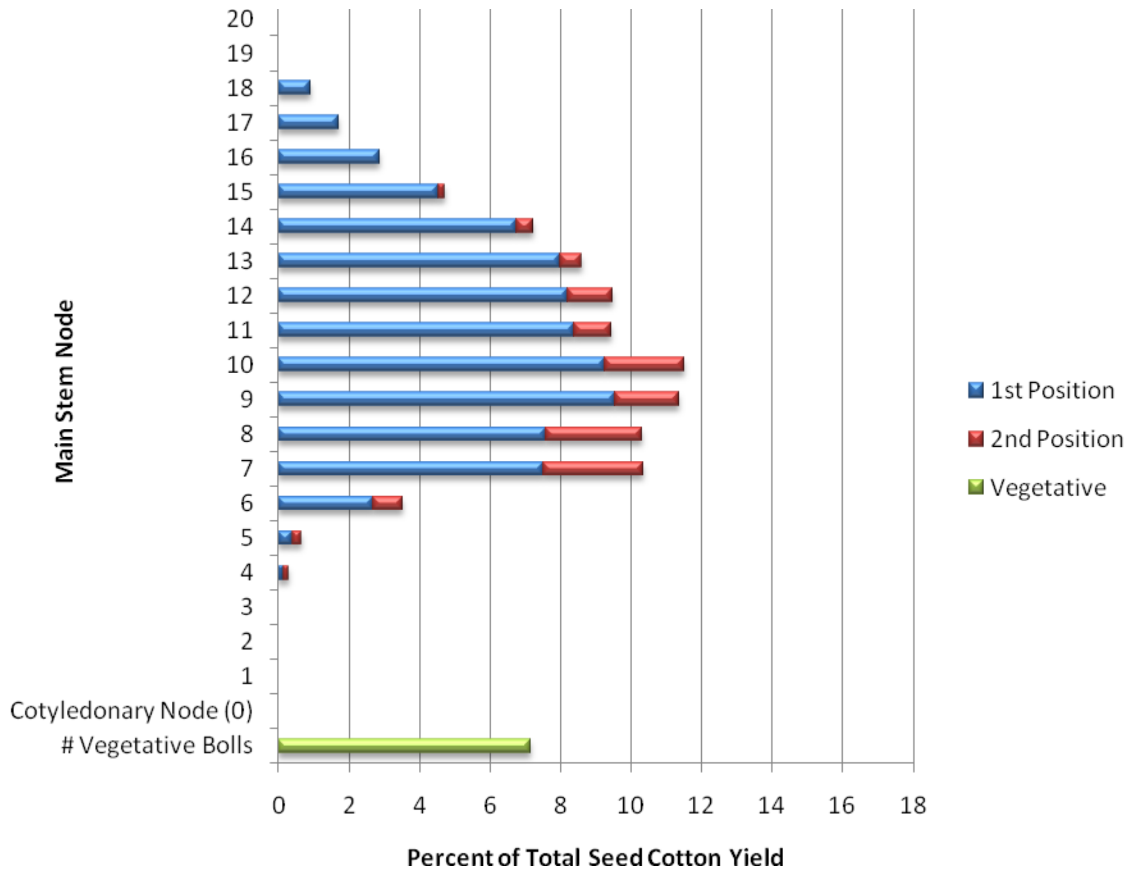

Figure 3. Harvest event 2 distribution of seed cotton yield by main stem node and fruiting position for field rep 4 (data from plot 16, 100% open bolls).

Total burr cotton, lint, and seed yields are shown by harvest treatment in table 3. Total burr cotton yields were different by harvesting treatment (p = 0.0086). Tukey's HSD test indicates that the pick then strip and conventional stripping treatments yielded more burr cotton per acre than the conventional picking treatment. The burr cotton yield for the pick then pick treatment was not different than any of the other treatments. These results were expected and are indicative of differences in trash level by harvesting method. No differences were observed in total lint yield or seed yield by harvest treatment and averaged 1645 lb/ac (3.4 bales/acre) and 3082 lb/acre, respectively across all treatments.

Table 3. Total burr cotton, lint, and seed yields by treatment.

	Conventional Picking	Conventional Stripping	Pick then Pick	Pick then Strip	MSD**
Burr Cotton Yield (lb/ac)	5227[B*]	6057[A]	5816[AB]	6140[A]	694.7
Lint Yield (lb/ac)	1652	1632	1685	1611	157.8
Seed Yield (lb/ac)	2957	3011	3158	3203	394.9

*Means by row with similar letters are not different according to Tukey's HSD test ($\alpha = 0.05$)
**MSD = minimum significant difference calculated according to Tukey's HSD test.

Although no differences were observed in total lint yields by harvest treatment, the lint yield for the twice over harvest treatments (pick then pick and pick then strip) varied by harvest date. Lint yields for the initial harvest (figure 4) accounted for approximately 70% of the total yield for both twice over harvest methods. This result is consistent with the percent open boll and harvest efficiency measurements considering that the crop was 80.3% open on average at the initial harvest event and the picker had an observed harvest efficiency of 88% (table 4) (e.g. 80.3% of total yield available for harvest x 88% harvest efficiency = 70.7% of total yield harvested).

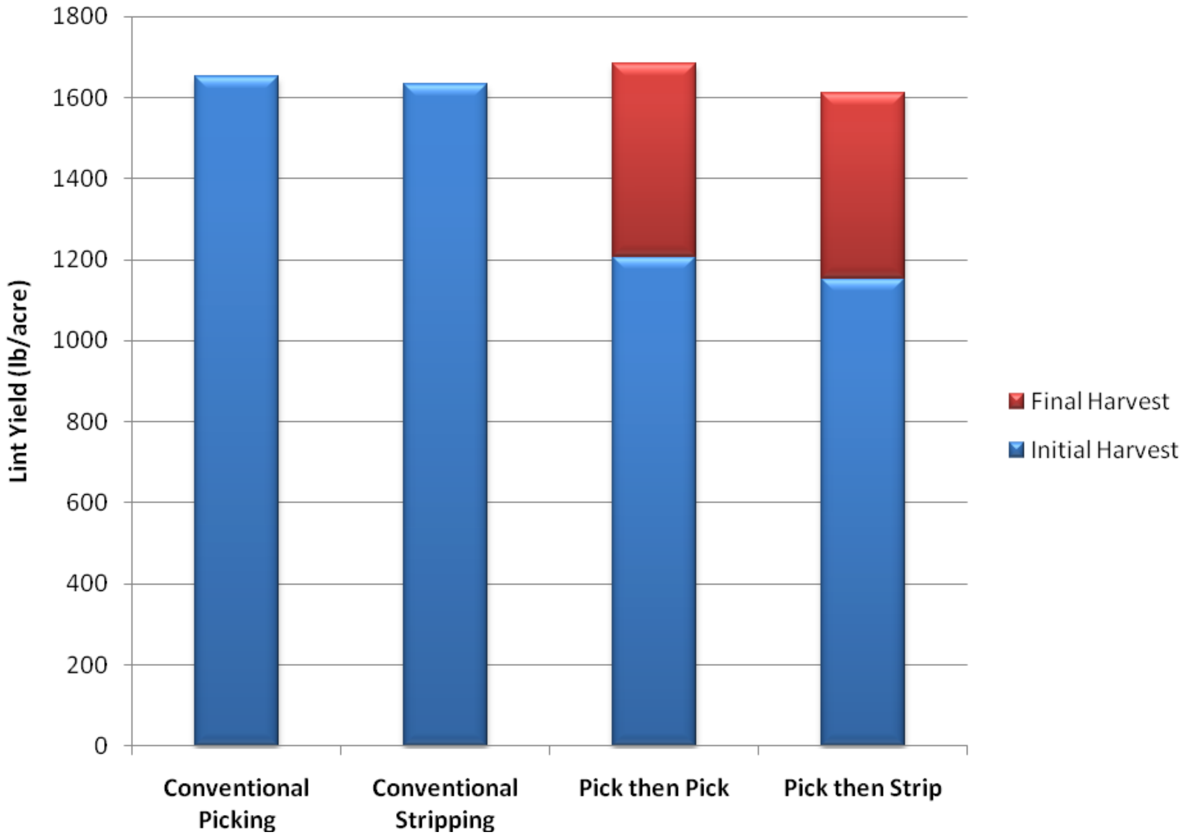

Figure 4. Lint yield by harvest treatment showing contribution by harvest date.

Table 4. Harvest efficiency measurement results and ginning performance parameters by harvest treatment.

Measurement	Conv. Picking	Conv. Strip	Pick then Pick Initial Harvest	Pick then Pick Final Harvest	Pick then Strip Initial Harvest	Pick then Strip Final Harvest	p>F	MSD**
Harvest Efficiency (%)	96.5^{A*}	99.9^{A}	88.0^{B}	89.9^{B}	88.2^{B}	97.0^{A}	<0.0001	***
Seed Cotton Cleaner Trash (lbs/bale)	157.5^{D}	388.1^{B}	290.6^{C}	181.5^{D}	306.8^{BC}	513.2^{A}	<0.0001	91.799
Lint Cleaner #1 Trash (lbs/bale)	16.2^{A}	20.1^{BC}	21.9^{CD}	17.5^{AB}	24.5^{D}	29.0^{E}	<0.0001	***
Lint Cleaner #2 Trash (lbs/bale)	6.1	6.8	6.5	6.8	7.0	7.5	0.2752	-
Seed Cotton Cleaning Rate (bales/hr-ft)	2.3^{A}	1.3^{C}	2.1^{AB}	1.8^{ABC}	2.5^{A}	1.4^{BC}	0.0002	0.7262
Ginning Rate (bales/hr)	4.8^{AB}	4.3^{BC}	4.3^{BC}	5.0^{A}	4.3^{BC}	4.0^{C}	0.0006	0.6015
Harvest Moisture Content (%)	5.42^{B}	5.52^{B}	9.41^{A}	5.32^{B}	9.19^{A}	6.09^{B}	<0.0001	1.0931
Suction Moisture Content (%)	7.48^{B}	6.67^{B}	23.95^{A}	6.78^{B}	20.06^{A}	9.09^{B}	<0.0001	6.0388
Ext. Feeder Apron Moisture Content (%)	5.83^{B}	5.52^{B}	13.77^{A}	5.35^{B}	13.24^{A}	5.37^{B}	<0.0001	1.3341
Lint Turnout (%)	31.6^{A}	27.0^{B}	28.0^{B}	31.6^{A}	27.0^{B}	24.5^{C}	<0.0001	1.6291
Seed to Lint Ratio	1.79^{C}	1.84^{BC}	1.93^{AB}	1.74^{C}	2.01^{A}	1.93^{AB}	<0.0001	0.1247

*Means by row with similar letters are not different according to Tukey's HSD test ($\alpha = 0.05$)
**MSD = minimum significant difference calculated according to Tukey's HSD test.
***Means seperation by Tukey-Kramer pairwise comparison test.

Harvest efficiency (see table 4) for both harvest events for the pick then pick treament and initial harvest for the pick then strip treatment were not different and averaged 88.7%. However, the harvesting efficiency of the picker was significantly higher for the conventional picking treatment (96.5%) than the other treatments where the picker was used. The harvesting efficiency of the picker was likely hindered during harvest event one due to the thick green condition of the crop. Harvest efficiency for the final harvest event for the pick then pick treatment was 89.9% and was lower than the conventional pick treatment. Low yield (478 lb/acre average) and tight boll conformations during the final harvest of the pick then pick treatment explain the low harvesting efficiency of the picker. The stripper harvesting efficiency was 99.9% for the conventional strip treatment but reduced to 97% for the final harvest event of the pick then strip treatment.

Differences by harvest treatment were observed for the seed cotton cleaner trash ($p < 0.0001$) and lint cleaner #1 trash ($p < 0.0001$). However, no differences by harvest method were observed in the lint cleaner #2 data ($p = 0.2752$). Excessive seed cotton cleaner trash (lb/bale) was observed for the initial harvest of the pick then pick and pick then strip treatments. This result was not expected and translated into reduced lint turnout values for the initial picker harvest for these two treatments. Further investigation of the harvest, suction, and extractor feeder apron moisture content data indicates a substantial increase in moisture content for the initial harvest events for the twice over harvest treatments. We believe that excessive moisture (20 – 24% moisture content at the suction telescope, table 4) contained in the trash in the ginning samples is the cause of the high seed cotton cleaner trash weights and low lint turnout values. Seed cotton cleaning rates were different by harvest treatment ($p = 0.0002$) as a consequence of trash level but were held within the recommended cleaning rate for the machinery used (< 2.5 bales/hr-ft). Ginning rate was also different by harvesting treatment ($p = 0.0006$). All ginning rates were within manufacturer recommended rates (5-6 bales/hr) and the small variation in ginning rate among treatments is not expected to influence fiber quality results.

HVI fiber quality analysis results for lint samples collected after two stages of lint cleaning are presented in table 5. MIC was different by harvest treatment ($p < 0.0001$) and was significantly higher for earlier harvest events for the twice over harvest treatments. The initial picker harvest for the pick then pick and pick then strip treatments had the highest MIC values of 4.5 and 4.4, respectively, since the machine was harvesting naturally opened cotton prior to the application of defoliant and boll opening chemicals. MIC was significantly higher for samples from the initial picker harvest event of the twice over harvest treatments than any of the stripper harvested samples. MIC decreased to 4.3 for the conventional pick treatment but was not different than the MIC for the conventional strip (4.2), final harvest of pick then pick (4.12), or initial harvest of the pick then strip treatments. Differences by treatment were observed for length ($p = 0.0043$) and uniformity ($p = 0.0012$) and favored picking. No differences were observed by treatment for the strength data. Differences were observed in the elongation data by treatment ($p = 0.0367$) but the magnitude of the differences is likely of little practical significance. Leaf grade differences by treatment were significant ($p = 0.0006$) but Tukey's HSD test inicated that only the final harvest event for the pick then strip treatment was higher (leaf grade = 2.3) than the other treatments (leaf grade range 1.0 – 1.3). Reflectance (Rd) values differed by harvest treatment ($p < 0.0001$) and were highest for the conventional pick (82.03%), conventional strip (81.55%), and pick then pick – final harvest treatments (81.10%) which were not different. Rd was lowest for the pick then pick (74.75%) and pick then strip (75.45%) initial harvest treatments due to the presence of high moisture content green leaf trash. Rd for the final harvest of the pick then pick treatment was intermediate to the other treatments at 78.95%. Plus b (yellowness) values trended similarly to the Rd values due to the presence of high moisture content trash. Yellowness values were highest for the initial picker harvest events of the pick then pick (10.13%) and pick then strip (10.05%) treatments. Yellowness decreased significantly from the first to the second harvest event and was 7.48% and 7.43% for the conventional pick and final harvest for the pick then pick treatments, respectively. The stripper harvested treatments occuring during the third harvest event had the lowest +b values and were both 6.65%. The Rd and +b values for the initial harvest events for the twice over harvest treatments translated into poorer predominate color grades than other treatments and resulted in decreased lint loan values. Loan values were different by harvest treatment ($p < 0.0001$) and means separation tests indicated that the mean loan values for samples harvested during the first harvest event and final harvest for the pick then strip treatments were significantly lower than samples collected from all other treatments.

Table 5. HVI fiber quality anlaysis results for lint samples collected after two stages of saw-type lint cleaning.

HVI Parameter	Conventional Picking	Conventional Stripping	Pick then Pick		Pick then Strip		p>F	MSD*
	-	-	Initial Harvest	Final Harvest	Initial Harvest	Final Harvest		
Predominate Color Grade	21	31	32	31	32 & 22	41		
MIC	4.3 BC	4.2 CD	4.5 A	4.12 CD	4.4 AB	4.05 D	<0.0001	0.1935
Length (in)	1.205 A	1.175 B	1.203 A	1.193 AB	1.205 A	1.180 AB	0.0043	0.0262
Uniformity (%)	82.8 A	81.6 CD	82.7 AB	82.0 ABC	82.9 A	81.7 CB	0.0012	1.0092
Strength (g/tex)	32.5	31.6	31.3	32.1	32.0	31.8	0.0605	-
Elongation (%)	6.3 AB	6.6 A	6.3 AB	6.2 B	6.3 AB	6.4 AB	0.0367	0.32
Leaf Grade	1.0 B	1.3 B	1.3 B	1.0 B	1.0 B	2.3 A	0.0006	0.7945
Rd (%)	82.03 A	81.55 A	74.75 C	81.10 A	75.45 C	78.95 B	<0.0001	1.2961
+b (%)	7.48 B	6.65 C	10.13 A	7.43 B	10.05 A	6.65 C	<0.0001	0.3865
Loan Value ($/lb)	0.5746 A	0.5683 A	0.5365 B	0.5711 A	0.5458 B	0.5503 B	<0.0001	0.0158

*MSD calculated according to Tukey's HSD test. Means in the same row followed by similar letters are not different at the 0.05 level of significance.

The results of AFIS fiber quality analysis for lint samples collected after two stages of saw-type lint cleaning are presented in table 6. Nep size was different by harvest method ($p = 0.0054$) and was generally smaller for picked samples and earlier harvest events. Nep content was different by harvest method ($p = 0.0005$) and showed a 22% average decrease for picker harvested samples compared to stripper harvested samples. Nep content was also lower for the initial harvest event for the pick then pick treatment than the final harvest event. Mean length by weight [l(w)] was different by harvest method ($p < 0.0001$) and was longer for the initial harvest of the twice over treatments and the conventional pick treatment. Harvesting treatment differences for both length by weight coefficient of variation [l(w) CV] ($p < 0.0001$) and upper quartile length (UQL) by weight ($p < 0.0001$) were observed and tended to favor the picker harvested samples from the first harvest event and the conventional pick treatment. Short fiber content by weight [SFC(w)] was lowest for the picker harvested samples from the first harvest event and the conventional pick treatment. SFC(w) was reduced by approximatley 25% on average for picked compared to stripped samples. Differences were observed by treatment for mean length by number [l(n)] ($p < 0.0001$), l(n) CV ($p < 0.0001$), and SFC(n) ($p < 0.0001$) and trends in the data followed that of the weight based length measurements. Differences by harvest method were observed in the total foreign material content ($p = 0.0001$) and dust content data ($p = 0.0001$). Trends for these two parameters were identical with lower foreign levels generally observed in picker harvested samples. Although not significantly different, the total foreign material and dust content levels for the initial harvest of the pick then pick treatment are considerably higher than those of samples from the initial harvest event of the pick then strip treatment. There is no currently known logical reason for this difference as it seems to be an anomoly in the data. No differences were observed by harvest treatment in the trash size data. Significant differences were observed by harvest method for the visible foreign material (VFM) data ($p = 0.001$). Although no differences were observed in the seed coat nep size (SCN size) data, SCN content was different by harvest treatment ($p = 0.0031$). Harvest date had a significant effect on the SCN content data as the amount of SCN approximately doubled between the initial and final harvest dates for the pick then pick treatment (initial harvest = 7.8 /g, final harvest = 15.3 /g). Fineness (Fine), immature fiber content (IFC), and maturity ratio were not different by harvest treatment and averaged 163.4 mTex, 7.66%, and 0.87, respectively. The result for fineness was expected as fineness is a genetic trait and only one variety (FiberMax 9180 B2F) was used. However, IFC and maturity ratio indicate that the fiber produced was quite mature.

Table 6. AFIS fiber quality analysis results for lint samples collected after two stages of saw-type lint cleaning.

AFIS Parameter	Conventional Picking	Conventional Stripping	Pick then Pick		Pick then Strip		p>F	MSD*
			Initial Harvest	Final Harvest	Initial Harvest	Final Harvest		
Nep size (um)	678^{AB}	691^{A}	673^{AB}	694^{A}	663^{B}	689^{A}	0.0054	24.241
Neps per Gm	315^{BC}	377^{AB}	293^{C}	375^{AB}	306^{BC}	415^{A}	0.0005	79.673
L(w) [in]	1.038^{A}	0.980^{B}	1.053^{A}	1.000^{B}	1.048^{A}	0.973^{B}	<0.0001	0.0363
L(w) CV [%]	34.2^{B}	37.5^{A}	33.4^{B}	36.6^{A}	33.4^{B}	37.5^{A}	<0.0001	1.7722
UQL (w) [in]	1.270^{AB}	1.225^{C}	1.280^{A}	1.245^{BC}	1.275^{AB}	1.218^{C}	<0.0001	0.0317
SFC (w) [%]	7.98^{B}	10.80^{A}	7.23^{B}	9.78^{A}	7.33^{B}	11.05^{A}	<0.0001	1.6308
L(n) [in]	0.818^{A}	0.738^{B}	0.840^{A}	0.765^{B}	0.835^{A}	0.730^{B}	<0.0001	0.0466
L(n) CV [%]	52.15^{B}	56.98^{A}	50.25^{B}	55.88^{A}	50.18^{B}	57.65^{A}	<0.0001	2.8481
SFC (n) [%]	26.15^{B}	32.25^{A}	24.13^{B}	30.45^{A}	24.23^{B}	33.00^{A}	<0.0001	3.5343
L5% (n) [in]	1.435^{A}	1.390^{B}	1.445^{A}	1.415^{AB}	1.443^{A}	1.385^{B}	<0.0001	0.0312
Total Cnt/g	172^{C}	273^{BC}	281^{ABC}	299^{AB}	178^{BC}	402^{A}	0.0001	121.84
Trash Size [um]	348	333	323	345	339	354	0.0875	-
Dust Cnt/g	141^{C}	224^{BC}	233^{ABC}	243^{AB}	147^{BC}	326^{A}	0.0001	99.871
Trash Cnt/g	31^{B}	49^{B}	48^{B}	56^{AB}	31^{B}	76^{A}	0.0003	26.388
VFM [%]	0.68^{B}	0.77^{B}	0.91^{AB}	1.07^{AB}	0.63^{B}	1.38^{A}	0.001	0.4849
SCN Size (um)	1077	1102	1228	1134	1099	1010	0.3725	-
SCN (Cnt/g)	9.3^{ABC}	9.0^{ABC}	7.8^{C}	15.3^{A}	8.3^{BC}	14.3^{AB}	0.0031	6.2616
Fine [mTex]	164.5	161.8	165.3	162.8	164.5	161.5	0.0547	-
IFC [%]	7.33	8.10	7.23	7.83	7.43	8.08	0.0212	0.9262
Mat Ratio	0.88	0.86	0.87	0.87	0.87	0.86	0.0649	-

*MSD calculated according to Tukey's HSD test.
Means in the same row followed by the same letter are not significantly different at the 0.05 level of significance.

A basic economic comparison (table 7) of the harvesting treatments was developed based on lint and seed revenue as well as harvest-aid application, harvesting, and ginning costs. Lint value per acre, calculated from lint yield and loan value (table 5), was not different by harvest method (p = 0.1851) and averaged $919.60/acre across treatments. Similarly, seed value was not different (p = 0.2464) by treatment and averaged $246.58/acre. Cotton seed was valued at $160 per ton for this comparison. Total revenue was not different by harvest treatment (p = 0.6438) and averaged $1166.18/ac. Harvest aid costs were different since additional chemicals were applied to stripper harvested plots to desiccate the crop. Harvest aid costs for the conventional pick and pick then pick treatments were $29/acre (Finish Pro @ 24 oz/acre: $11.81/ac + Ginstar @ 8 oz/acre: $12.19/acre + $5/acre application cost) while the conventional strip and pick then strip treatments incurred an additional $14.89 /acre for desiccant application (Gramoxone Inteon @ 32 oz/acre: $9.89/acre + $5.00/acre application cost). Harvesting costs were calculated using $0.10 /lint lb for picked cotton and $0.08 /lint lb for stripped cotton and differences were observed by harvest treatment (p = 0.004). Harvest cost for the conventional strip ($130.56/acre) treatment was lower than all other treatments. Ginning costs were calculated using $3/cwt incoming seed cotton weight and differences were observed by harvest treatment (p = 0.0086). Ginning costs were not different for the conventional strip ($181.70/acre) and pick then strip ($184.20/acre) treatments but were higher than the conventional pick treatment ginning cost ($156.80/acre). Ginning cost for the pick then pick treatment was not different than any other treatment ($174.47/acre). Total harvest and ginning cost was different by harvest method (p = 0.0344) and ranged from $342.96/acre for the conventional pick treatment to $389.16/acre for the pick then strip treatment. Total harvest and ginning costs for the conventional strip ($356.15/acre) and pick then pick ($371.97/acre) treatments were not different than the conventional pick or pick then strip treatments, which were different. Net income was highest for the conventional picking treatment ($842.66/acre) which was not different than the conventional strip ($812.11/acre) or pick then pick ($801.36/acre) treatments. The pick then strip treatment had the lowest net income of $748.36/acre and was only significantly different than the conventional pick treatment.

Table 7. Basic economic comparison of harvest treatments.

	Conventional Picking	Conventional Stripping	Pick then Pick	Pick then Strip	p>F	MSD
Income						
Lint Value ($/ac)	$ 949.05	$ 927.40	$ 920.69	$ 881.27	0.1851	-
Seed Value ($/ac)	$ 236.57	$ 240.85	$ 252.63	$ 256.25	0.2464	-
Total Revenue ($/ac)	$ 1,185.62	$ 1,168.26	$ 1,173.32	$ 1,137.52	0.6438	-
Expenses						
Harvest Aids ($/ac)	$ 29.00 A	$ 43.89 B	$ 29.00 A	$ 43.89 B	<0.0001	$ -
Harvesting ($/ac)	$ 157.15 A	$ 130.56 B	$ 168.50 A	$ 161.07 A	0.004	$ 25.09
Ginning ($/ac)	$ 156.80 B	$ 181.70 A	$ 174.47 AB	$ 184.20 A	0.0086	$ 20.83
Total Harvest & Ginning ($/ac)	$ 342.96 B	$ 356.15 AB	$ 371.97 AB	$ 389.16 A	0.0344	$ 41.88
Net Income ($/ac)	**$ 842.66** A	**$ 812.11** AB	**$ 801.36** AB	**$ 748.36** B	0.0242	$ 77.54

Summary

One variety of cotton (FiberMax 9180 B2F) was produced on a drip irrigated field in Lubbock, TX and harvested using conventional harvesting equipment applied at different levels of final crop maturity defined by percent open bolls. Box mapping was conducted to document the within-plant distribution of yield and fiber quality for the crop at 80% and 100% open bolls. Seed cotton yield distribution data indicates that approximately 95% of the crop yield is located below main stem node 14 at 80% open bolls but decreases to approximately 82% at 100% open bolls. The majority of the crop yield is located in first position bolls. We are in the process of developing distributions for fiber quality and lint value based on HVI and AFIS analyses of ginned lint samples.

Lint yield for the crop was not observed to be different between harvest treatments. The harvesting efficiency of the spindle type cotton picker was reduced to approximately 90% for initial harvest events when the crop was still green prior to defoliation. After defoliation, harvesting efficiency for the picker increased substantially to over 96% for the conventional picking treatment while low yields and tight boll conformations kept picking efficiency low for the final harvest event of the pick then pick treatment. Harvesting efficiency for the stripper harvester remained high (~97 - 99%) as seen in previous work.

HVI fiber analysis indicated differences by harvest treatment for most parameters except strength and tended to favor picking and earlier harvest events. MIC values ranged from 4.1 to 4.5 indicating that the fiber was mature but was highest for the initial harvest event using the spindle picker. However, lint loan value for the initial harvest event for the twice over harvest treatments using the picker was lower than other treatments due to poor color grades caused by the presence of green leaf trash with high moisture content. AFIS fiber analyses indicated improvements in terms of nep content and short fiber content for picked cotton harvested earlier.

Economic comparison of the harvest treatments under the conditions experienced during the 2009 growing season with regard to net value per acre indicates that the conventional pick treatment was not significantly different than the conventional strip or pick then pick treatments but returned more per acre than the pick then strip treatment. These findings were based on agronomic comparisons assuming equal production costs up to the time of harvest, consistent harvest costs regardless of yield (i.e. cost to pick remains at $0.10/lint lb for 1 bale/acre or 3 bale/acre yield), and there is no price premium above CCC loan value for high quality cotton.

The findings presented in this manuscript are representative of a crop with relatively high fiber maturity. Additional work planned for the 2010 crop year will focus on documenting yield and fiber quality distributions as well as harvest treatment effects on fiber quality and net return for a crop with higher yield, lower average MIC, and wider fiber maturity distribution.

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