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Effects of Harvesting Methods on Foreign Matter Content, Fiber Quality, and Yarn Quality from Irrigated Cotton on the High Plains

William B. Faulkner, Research Associate

Texas A&M University, Dept. of Biological and Agricultural Engineering, 2117 TAMU, College Station, Texas, 77843-2117

John D. Wanjura, Agricultural Engineer

USDA-ARS Cotton Production and Processing Research Unit, 1604 E. FM 1294, Lubbock, TX 79403

Bryan W. Shaw, Associate Professor

Texas A&M University, Dept. of Biological and Agricultural Engineering, 2117 TAMU, College Station, Texas, 77843-2117

Eric F. Hequet, Associate Director

International Textile Center, Texas Tech University, Box 45019, Lubbock, Texas, 79409-5019

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Abstract. *Picker and stripper harvest systems were compared for harvesting irrigated cotton on the High Plains. Stoneville 4554 B2RF was harvested using a picker harvester and a stripper harvester with and without field cleaning. The effect of harvest treatment on foreign matter, fiber quality, and yarn quality were compared. Picked cotton generally had less foreign material, higher micronaire and a higher length uniformity than stripped cotton, likely due to the presence of more immature fibers in stripped cotton. Little difference was detected between harvest treatments in carded yarn quality. However, more substantial differences were detected in the quality of carded and combed yarns based on harvest treatment.*

Keywords. Picker, stripper, fiber quality, yarn quality, HVI, AFIS, cotton

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Introduction

Over a fourth of the cotton bales produced in the United States since 2002 have been produced in Texas (USDA, 2006) with most of that cotton coming from the High Plains region. Five of the eight distinct cotton producing regions in Texas, including the High Plains, Rolling Plains, Central Blackland, Coastal Bend, and Winter Garden regions, are primarily harvested using stripper harvesters, while the Upper Gulf Coast, Rio Grande Valley, and El Paso/Trans-Pecos regions primarily use picker harvesters (Nelson et al., 2001). Approximately 85 percent of the cotton produced in Texas is currently stripper harvested (Glade et al., 1996).

Unlike picker harvesters, which use spindles to remove seed cotton from the boll of the plant, stripper harvesters use brushes and bats that indiscriminately remove seed cotton, bolls, leaves, and many branches from the stem of the plant. As a result, stripper harvested cotton contains more foreign matter than spindle picked cotton. This increased foreign matter leads to higher transportation costs per bale to haul modules to the gin as well as potentially higher costs of processing the cotton, due to the use of additional cleaning machinery at the gin. Foreign matter may be reduced by the use of a field cleaner (often called a burr extractor), but foreign matter levels are still greater than found in spindle picked cotton.

Stripper harvesters do have several advantages over picker harvesters, including lower purchase prices, fewer moving parts in the row units, lower fuel consumption and maintenance requirements, and faster ground speeds in low yielding cotton. Picker harvesters, however, pick cleaner cotton, are perceived to maintain fiber quality characteristics better than strippers, and are able to harvest cotton at higher speeds in high yielding stands.

As irrigation technology has improved and new cotton varieties have been introduced and adopted on the High Plains, yields in the region have dramatically increased, sometimes reaching four to five bales per acre. It is estimated that between 300,000 and 400,000 acres of drip irrigation has been installed on the High Plains in the past ten years for cotton production, and over 1.1 million acres are irrigated with center pivot systems equipped with high efficiency application packages. Furthermore, foreign textile mills continue to raise their standards for fiber quality as cotton spinners are forced to compete with synthetic fibers that are not plagued with fiber contamination and degradation. These increased yields and higher quality demands have the potential to make harvesting High Plains cotton with pickers an attractive option.

While research has been conducted to compare fiber quality between stripper and picker harvested cotton, most of this research focused on lower yielding stands of cotton and used harvest machinery that was not representative of modern harvest systems. Furthermore, fiber quality traits are not always sufficient to indicate spinning performance and yarn quality, especially if the only fiber quality traits analyzed are those indicated by the current USDA cotton classing system.

Comparing fiber quality between picker and stripper harvested cottons, Brashears and Hake (1995) found better leaf grades in Paymaster HS26 harvested with a picker harvester versus a stripper harvester with and without field cleaning, but there was no difference in leaf grade between the harvest treatments for Stoneville 132. No significant effects were seen in High Volume Instrument (HVI) staple length, micronaire, strength, length, or length uniformity between harvest methods. The two-row picker used by Brashears and Hake (1995) does not reflect the advances in technology of modern harvest machinery, making application of this study to modern production systems questionable.

Vories and Bonner (1995) compared fiber quality between stripped (with field cleaning) and picked dryland cotton in Arkansas. None of the HVI parameters were significantly different between harvest methods. In 1992, when weather conditions were more harsh, fiber quality indices were better for picker harvested cotton than for stripper harvested cotton, confirming the finding of Kerby et al. (1986) that grade differences between harvest methods are most pronounced during years of adverse conditions. Though not significantly different, micronaire values for stripped cotton were lower than those of picked cotton for two of the three years of the study. Again, the brush stripper used in the Vories and Bonner (1995) study (an Allis Chalmers 880 with alternating brushes and flaps) does not represent modern harvesting machinery, making extrapolation of these results to modern production systems tenuous.

Baker and Brashears (2000) evaluated the effect of field cleaners on fiber and yarn quality of three stripper varieties of cotton. They found that lint trash content was significantly reduced at each stage of lint cleaning by using field cleaners, thus resulting in somewhat better color and leaf grades. Half of the samples analyzed indicated a one leaf grade improvement from use of a field cleaner. Field cleaned cotton also had some higher micronaire and maturity ratios and reduced nep counts in fiber and yarn. For open-end spun yarn, the field cleaned cotton produced yarn with slightly higher evenness coefficient of variation (CV) and more thin places. All other measured yarn factors were unaffected by the use of a field cleaner.

Brashears and Baker (2000) compared the quality of two varieties of cotton harvested using a finger stripper, a brush roll stripper (both with field cleaners), and a spindle picker. Leaf grades were similar for Paymaster 2200 regardless of harvest method, while the leaf grade for picker harvested D&PM 1220 was significantly lower for the same variety harvested with both strippers. For both varieties, the fiber length of picked cotton was longer and the micronaire was higher than that of the same variety that was stripped. Fiber length of brush stripped cotton was also significantly longer than finger stripped cotton. For both varieties, nep counts were significantly lower for the picker harvested cotton than for the stripped cotton.

Willcutt et al. (2002) compared lint quality as affected by harvester type for picker varieties grown on the Mississippi delta. They observed better values in nep counts, short fiber content by weight, visible foreign matter and immature fiber content for picked cotton than stripped cotton samples. Classer staple, HVI length, uniformity, and strength were not affected significantly by harvest method.

Faircloth et al. (2004) evaluated turnout, fiber quality, and loan value from cotton harvested using brush strippers versus spindle harvesters in northeast Louisiana. Yields in this study ranged from 1.23 to 2.70 bales per acre (assuming 480 pound bales). Few statistically significant differences in fiber quality from the two harvesting treatments were observed, but trends of decreased micronaire and increased color grade in stripper harvested cotton were seen. Incorporating differences in yield, fiber quality, and input costs, Faircloth et al. (2004) determined that stripper harvesting increased overall revenue during one of the two years of the study. However, whereas stripper harvested cotton traditionally requires more seed cotton cleaning and/or lint cleaning at the gin than spindle picked cotton leading to greater fiber breakage, additional cleaning, and higher ginning costs, ginning treatments were not varied between stripper and picker harvested samples (J.C. Faircloth, personal communication, 04 October 2006). This lack of additional cleaning led to an incomplete analysis of typical system inputs. Furthermore, the varieties and yields used in the study are not representative of those used on the High Plains and make extrapolation to this region troublesome.

McAlister and Rogers (2005) investigated the effect of harvesting method on fiber and yarn quality from Ultra-Narrow-Row cotton grown in South Carolina. Due to varietal differences, the use of Ultra-Narrow-Row cotton, and the extreme weathering of the cotton before harvest, the applicability of the results of this study to the High Plains is questionable. However, the protocols for fiber and yarn testing employed in the McAlister and Rogers study are helpful in determining the effect of harvesting method throughout the processing chain.

The objective of this research was to holistically examine the possibility of using picker harvesters to replace stripper harvesters on the High Plains of Texas. Specifically, this paper focuses on differences in foreign matter content, fiber quality, and yarn quality from cotton harvested on the High Plains of Texas using a picker harvester, a stripper harvester with a field cleaner, and a stripper harvester without a field cleaner. Each of these components will later be incorporated into a larger cost-benefit analysis to determine the feasibility of replacing stripper harvesters with picker harvesters on the High Plains of Texas.

Methods

Irrigated cotton (Stoneville 4554 B2RF) was produced on 76.2-cm (30-inch) rows at a commercial farm on the High Plains of Texas. Production practices throughout the growing season were typical for the High Plains region. Cotton was harvested in late October/early November 2006 using a six-row John Deere 9996 spindle picker with Pro-16 row units equipped with scrapping plates, a six-row John Deere 7460 stripper harvester with field cleaner, and the same stripper harvester bypassing the field cleaner. One module of seed cotton was made from cotton harvested using each of the harvesters. Defoliation and harvest aid treatments were identical for both picked and stripped cotton based on the producer's observations of harvest readiness. Prior to harvest, the harvesting method used in each pass of the field was completely randomized. Both the picker and stripper harvesters used were six-row models, so each pass consisted of a block of twelve rows.

Before mechanical harvest, three 150-g samples of seed cotton were hand-picked for moisture analysis, which was conducted according to the protocol of Shepherd (1972). For moisture content analysis, plants were selected at random and all bolls on a given plant were collected and placed in a sealed moisture can. Five samples of seed cotton were also hand harvested from each plot and ginned on a breeder gin at the Texas Agriculture Experiment Station in Lubbock, Texas, to verify that the fiber quality from each plot before harvest was comparable.

During harvest, four 140-kg samples of seed cotton were collected from the module builder for each harvest method for ginning on a commercial-size gin to obtain lint samples for yarn quality analysis. Five 900-g samples were also taken at random from each module for fractionation analysis by pulling samples from the module builder. Samples were placed in bulk seed bags and stored for ginning.

Large samples were ginned at the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, Texas, on a commercial-size gin. The ginning order for the 140-kg samples was completely randomized. Due to late season rains, the leaf trash was difficult to separate from the seed cotton, so cotton from all harvesting treatments was subjected to the same cleaning regime, including two stages of seed cotton cleaning (using a tower dryer, incline cleaner, and a stick machine) and two stages of saw-type lint cleaning. Three sub-samples were collected from each lot of seed cotton from the lint slide for HVI and AFIS analyses.

Foreign Matter Content

The amount of foreign matter in the seed cotton harvested using each method was determined using the Pneumatic Fractionator Method described by Shepherd (1972). Large foreign matter was removed from the samples by hand before fractionation and was categorized into burrs, sticks, and other. The mass of the entire sample and those of each fraction were determined using an Ohaus scale (Model CT1200-S, Florham Park, NJ) with a 0.1 g resolution.

Fiber and Yarn Quality

Lint samples were conditioned at 65% RH ± 2% and 21°C ± 1 (according to ASTM D1776-04 Standard Practice for Conditioning of Textiles) for fiber quality analysis and tested using an HVI (Model 900A, USTER®) with 4 micronaire readings, 4 color readings, and 10 length and strength readings per sample and the AFIS with 5 replications of 3,000 fibers tested per sample at the International Textile Center in Lubbock, Texas, before undergoing carded and combed yarn tests. Carded and combed samples were spun on a Suessen Elite ring spinning frame with a 40Ne yarn count and a twist of 4.2 (weaving twist). Yarn count and skein break tests were conducted using a Scott Tester (ten bobbins tested per sample); yarn force to break, elongation, tenacity, and work to break were tested using a Uster Tensorapid 3 (ten bobbins tested per sample and ten breaks per bobbin); and yarn evenness was tested using an Uster Tester 3 (ten bobbins tested per sample and 400 meters per bobbin). Hand harvested samples and lint samples collected before and after lint cleaning also underwent similar conditioning and testing at Cotton Incorporated in Cary, North Carolina. Lint samples tested at different locations were not compared.

All treatment means were compared using the General Linear Model function in SPSS (SPSS, Inc., Chicago, IL). A multivariate analysis of variance (MANOVA) was conducted to determine overall differences between harvest treatments before conducting pair-wise comparisons. The null hypothesis tested in all cases was that means in each harvest treatment were equal. Means were compared using the Least Significant Difference (LSD) pair-wise multiple comparison test. A 0.05 level of significance was used in all tests except were noted differently.

Results and Discussion

The average moisture content of all seed cotton samples was 6.59 percent (wet-basis). No significant differences were detected in moisture content between treatments, so moisture content was not considered to affect harvester performance.

Foreign Matter Content

The composition of seed cotton from each harvester treatment as determined by fractionation analysis is shown in table 1. Treatment differences were detected using MANOVA ($p < 0.0005$ using Roy's largest root).

Table 1. Percent composition of harvested material.[a]

	Picked	**Stripped with FC**	**Stripped without FC**
Lint and Seeds	94.0 x	82.6 y	73.1 z
Total Foreign Material	5.2 x	16.0 y	25.8 z
Hulls	2.1 x	10.4 y	19.9 z
Sticks	0.5 x	1.5 y	2.0 y
Leaf	2.2 x	3.8 y	3.6 y
Pin Trash	0.3 x	0.3 x	0.3 x
Motes	0.09 x	0.05 x,y	0.02 y

[a] No significant differences were detected ($\alpha = 0.05$) between means in the same row followed by the same letter.

The percent of hulls ($p<0.0005$) and total foreign material ($p<0.0005$) was higher for the stripper without field cleaner than the stripper with field cleaner. The amount of foreign material of all classes in seed cotton, with the exception of pin trash, was higher for the stripper without the field cleaner than the spindle picker ($p=0.036$). Spindle picked seed cotton had a lower percentage of total foreign material, hulls, sticks, and leaf than the seed cotton that was stripped and field cleaned ($p=0.014$).

Fiber Quality

The results of HVI and selected parameters of AFIS testing are shown in tables 2 and 3, respectively. Caution should be used when interpreting results because fiber maturity for all samples was low. Results of MANOVA analyses indicated that overall treatment differences were not detected for HVI results at 95% confidence level, so the results of pair-wise comparisons of HVI data should be analyzed cautiously. Treatment differences were detected using MANOVA when analyzing results of AFIS tests ($p<0.0005$ using Roy's largest root).

Table 2. Results of HVI analysis.[a]

	Picked	**Stripped with FC**	**Stripped without FC**
Micronaire	3.5 x	3.2 y	3.2 y
Length (in.)	1.11 x	1.09 y	1.10 x,y
Uniformity (%)	80.4 x	79.4 y	79.2 y
Strength (g/tex)	27.1 x	26.2 x	26.6 x
Elongation (%)	8.4 x	8.7 x	8.5 x
Reflectance (%)	81.6 x	81.1 x,y	80.9 y
Yellowness	8.1 x	8.5 x,y	8.7 y
Leaf	2.0 x	2.5 x	2.3 x

[a] No significant differences were detected ($\alpha = 0.05$) between means in the same row followed by the same letter.

Table 3. Selected results of AFIS analysis.[a]

	Picked	**Stripped with FC**	**Stripped without FC**
Nep count (neps/g)	561 x	661 x,y	702 y
Short fiber by weight (%)	16.1 x	17.3 x	17.7 x
Visible foreign matter (%)	1.06 x	1.18 x	1.15 x
Immature fiber content (%)	12.8 x	13.7 x	13.8 x
Maturity ratio	0.78 x	0.78 x	0.77 x

[a] No significant differences were detected ($\alpha = 0.05$) between means in the same row followed by the same letter.

Micronaire for spindle picked cotton was significantly higher than for either stripper treatment. Stripper harvesters tend to have higher harvesting efficiencies than pickers; however, the increase in lint fiber harvested is typically comprised of less mature fibers that therefore have lower micronaire values. Length uniformity was also significantly better for picked cotton versus both stripper treatments. Both micronaire and length uniformity values for picked cotton were within the base market value range, while both stripper treatments led to micronaire and length uniformities in the discount range. Average AFIS length distributions by number for all treatments are shown in fig. 1. All length distributions are poor and skewed to the right due to the lack of maturity. Nevertheless, we can see that the fiber length distribution of the picked cotton is slightly better (less fiber fragments, less short fibers, and more of the longer fibers).

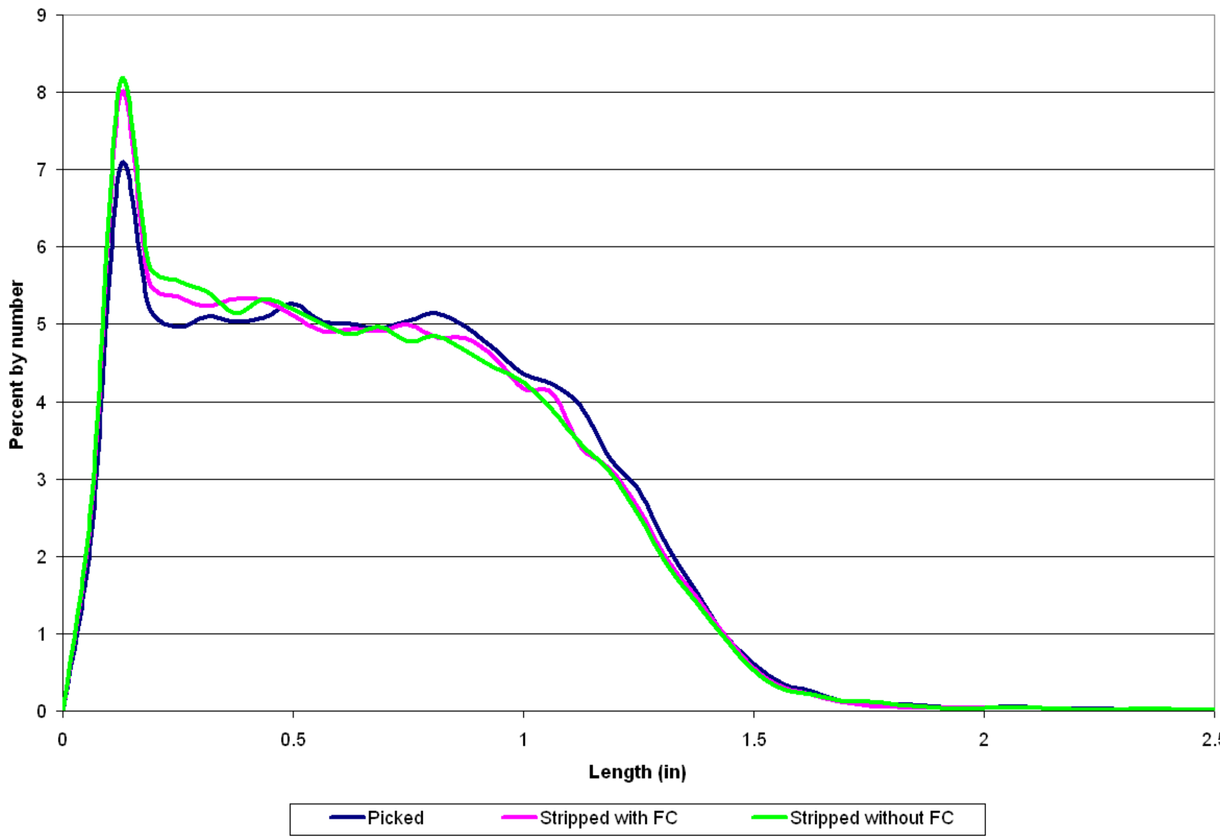

Figure 1. AFIS length distributions by number.

No significant interactions were detected between harvest treatment and lint cleaning for fiber quality parameters testing using HVI and AFIS. As expected, lint cleaning resulting in a greater reduction in visible foreign matter for both stripper treatments than for picked cotton. However, no differences were detected in the change in length, strength, nep count, nor nep size of fibers between harvest treatments suggesting that differences in fiber quality reported in tables 2 and 3 are the result of harvest treatment rather than interactions between harvest treatment and lint cleaning. Loan values for picked, field cleaned, and non-field cleaned cotton were $0.572, $0.542, and $0.527 per pound, respectively, with significant differences detected between all treatments.

Yarn Quality

Selected results of carded and combed yarn testing are shown in tables 4 and 5, respectively. Treatment differences were detected in carded yarn tests (p=0.037 using Roy's largest root) but not carded and combed yarn tests (p=0.227 using Roy's largest root) using MANOVA. Therefore, pair-wise comparison tests of carded yarn tests may be analyzed as presented while combed yarn tests should be analyzed with more caution.

Table 4. Selected results of carded yarn analysis.[a]

	Picked		Stripped with FC		Stripped without FC	
	Value	**Quality[b] (%)**	**Value**	**Quality[b] (%)**	**Value**	**Quality[b] (%)**
CSP (lb.Ne)	1786.3 x	>95	1759.5 x	>95	1741.5 x	>95
Elongation (%)	7.80 x	<5	7.91 x	<5	7.87 x	<5
Tenacity (cN/tex)	11.89 x	>95	11.86 x	>95	11.94 x	>95
CV (%)	22.67 x	>95	23.43 y	>95	23.32 x,y	>95
Thin Places	597 x	>95	742 x	>95	736 x	>95
Thick Places	1641 x	>95	1837 x	>95	1808 x	>95
Neps +200%	1542 x	>95	1787 x	>95	1785 x	>95
Hairiness	4.75 x	53	5.08 y	74	5.16 y	78

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.

[b] Quality percentile is based on global yarn quality statistics (USTER, 2001).

Table 5. Selected results of carded and combed yarn analysis.[a]

	Picked		Stripped with FC		Stripped without FC	
	Value	**Quality[b] (%)**	**Value**	**Quality[b] (%)**	**Value**	**Quality[b] (%)**
Noils (%)	17.05 x	N/A	17.65 x	N/A	18.52 y	N/A
CSP (lb.Ne)	2058.0 x	>95	2050.1 x	>95	2037.5 x	>95
Elongation (%)	7.98 x	<5	8.00 x	<5	8.01 x	<5
Tenacity (cN/tex)	13.42 x	>95	13.40 x	>95	13.26 x	>95
CV (%)	16.81 x	>95	17.24 y	>95	17.37 y	>95
Thin Places	47 x	89	58 y	92	55 x,y	92
Thick Places	290 x	85	348 y	87	360 y	87
Neps +200%	1030 x	>95	1260 y	>95	1320 y	>95
Hairiness	4.22 x	24	4.41 y	45	4.49 y	52

[a] No significant differences were detected (α = 0.05) between means in the same row followed by the same letter.

[b] Quality percentile is based on global yarn quality statistics (USTER, 2001).

Little difference was detected in carded yarn quality based on harvest treatment with the exception of hairiness. However, greater differences were detected in carded and combed yarn quality indices. In addition to the reduced percentage of noils seen in picked and field cleaned cotton, picked cotton had a smaller CV, fewer thick and thin places, fewer neps, and was less hairy than both stripped treatments. It should be noted, however, that combing is not typically performed on fibers with a staple shorter than 36, which was the case for all three harvest treatments. Compared to global averages, the yarn quality indices reported above for all harvest treatments indicate relatively poor yarn quality except when considering elongation. However, due to the immaturity of fibers analyzed and the use of only one variety of cotton for these tests, it is unclear whether this reduced quality is endemic of the High Plains region, variety specific, or attributable to lack of maturity.

Conclusion

Harvest treatments were compared for a variety of cotton commonly grown on the High Plains of Texas. Foreign matter, fiber quality, and yarn quality were compared for cotton harvested using a spindle picker, a brush-roll stripper with a field cleaner, and the same stripper harvester without a field cleaner. Foreign matter content of seed cotton was significantly different for all three treatments, with picked cotton having the lowest foreign matter content and non-burr extracted seed cotton having the highest. All samples underwent similar cleaning regimes during ginning.

Micronaire, length, and length uniformity as measured by HVI were better for picker harvested cotton than for stripped cotton leading to a higher loan value for the producer. While nep counts for picked cotton were lower than for non-burr extracted cotton, short fiber content, visible foreign matter, immature fiber content, and maturity ration were identical for all harvest treatments.

Little difference in carded yarn quality was seen between harvest treatments, while more pronounced differences favoring picked cotton were seen in carded and combed yarn analyses. However, textile mills rarely comb fibers as short as those analyzed in this study.

The results of this study indicate that producers may realize greater fiber quality and lint value by using picker harvesters as indicated by USDA classing office data. However, there is not currently enough data to adequately determine the effect of harvest treatment on yarn quality from High Plains cotton. Further research is needed utilizing more varieties and more mature cotton before conclusive results can be determined. However, results of this study indicate the need for more extensive fiber and yarn quality analyses than can be determined from HVI data alone when evaluating production system alternatives.

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