CROP RESIDUE INVENTORY ESTIMATES FOR TEXAS HIGH PLAINS COTTON

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Abstract

Interest in the use of cotton crop by-products for the production of bio-fuels and value-added products is increasing. Research documenting the availability of cotton crop by-products after machine harvest is needed. The objectives of this work were to document the total biomass production for modern cotton cultivars under irrigated conditions, document the production of lint, seed, and foreign matter for modern cultivars, and demonstrate the value of cotton by-products separated by the gin under unique environmental conditions encountered during 2011. The results of this work indicate that approximately half of the total biomass produced by two modern cultivars under irrigated conditions remained in the field after machine harvest. Lint turnout for cotton harvested using a picker, stripper with field cleaner, and stripper without field cleaner averaged 35%, 30%, and 25%, respectively for seven recent cotton harvesting and ginning studies. These turnout values were measured for modern cotton cultivars grown under production conditions typical to the Southern High Plains of the US and follow closely with turnout values reported in earlier publications. The value of cotton by-product material for livestock feed can be considerable under severe drought conditions, like those experienced in 2011. Thus, some producers may consider bypassing the field cleaner onboard a stripper harvester to increase the amount of foreign material taken to the gin and thereby increase economic revenue. If the trash sales price (or the credit for gin trash from the gin) is less than the gross ginning price, producers should not consider bypassing the field cleaner on a cotton stripper. If the trash sales price is equal to or greater than the gross ginning price, producers may realize an economic benefit by bringing additional foreign material to the gin (i.e. bypassing a cotton stripper field cleaner). However, producers should also consider potential decreases in lint value and harvest productivity prior to deciding to bypass the field cleaner on a cotton stripper.

Introduction

It is recognized that cotton produces two unique economically valuable products: fiber and seed; however, studies have also shown value for by-products removed at the gin such as leaf, stick, carpel material (Holt et al. 2000), and the non-harvested cotton stalks (e.g., Youngquist et al., 1996). Recent interest in the non-fiber and seed biomass production of cotton has been increased due to biofuel mandates. Examples include: incineration of gin byproducts (e.g., compression of gin trash into pellets, Holt et al., 2003); conversion of gin by-products to a combustible gas through pyrolysis (Aquino et al., 2007); and use of the non-harvested stalks as an energy feedstock (Luke-Morgan et al., 2008). Luke-Morgan et al. (2008) note the importance of harvesting and transportation costs; with stalk dry matter per unit area being an important parameter in the economic evaluation. Furthermore, discussions on green-house gas emissions and carbon sequestration also require data on total crop biomass production, not just yield related information (Nalley et al., 2011).

There have been many studies that have examined the biomass partitioning of cotton from a physiological perspective, often in an effort to increase the fraction attributed to lint and seed. For example, Wells and Meredith (1982) grew cultivars released between 1905 and 1978 to examine differences in development and biomass partitioning. Overall their study indicated little difference in leaf dry weight between the cultivars, but did find the more recently released cultivars had a lower stem weight than older cultivars. One measure of biomass partitioning often used in physiological studies is the harvest index (HI). Nalley et al. (2011) did a review of cotton experts in the United States and estimated an average HI for cotton of 0.45 with values ranging from 0.24 to 0.57 (the standard deviation of estimates average by state was 0.06). The range and mean HI reported by Nalley et al. (2011) are in agreement with other studies in the last 20-years summarized in Table 1. Harvest index can be influenced by many factors during a growing season such as crop stress (e.g., nutrient deficiencies and water shortages), and insect infestations. Furthermore, the point in time at which the estimate is made can also be significant as cotton naturally loses leaves late in season, and what biomass is actually present in the field after harvest may not always be represented by studies that focus on crop physiology as the data is often collected prior to final harvest.

The objectives of this work are to:

1. Document the total biomass produced by an irrigated Texas High Plains cotton crop differentiating the portions that are transported to the gin and that remain in the field after harvest,
2. Document lint turnout, seed production, and foreign matter content of modern cotton cultivars produced in the Texas High Plains, and
3. Demonstrate the value of gin byproducts as encountered through unique environmental conditions during the 2011 cotton production season.

Table 1. Summary of past studies with data collected that allowed calculation of the harvest index (HI) for cotton.

Citation	Years	Number of Cultivars	Location	Average HI	Standard Deviation of HI
Bhattarai et al., 2005	2001, 2002	2	Australia	0.60	0.03
Colaizzi et al., 2003	1998, 1999	1	AZ	0.36	
Fitzgerald et al., 2006	2001	1	AZ	0.56	0.05
Mauney et al., 1994	1989, 1991	1	AZ	0.43	0.08
Ortiz et al., 2010	2007	1	GA	0.48	0.02
Pettigrew, 2003	1995 to 1997	3	MS	0.48	0.04
Pettigrew, 2008	2003 to 2005	1	MS	0.41	0.10
Wells and Meredith, 1982	1982	12	MS	0.44	0.07
			Average:	**0.47**	**0.06**

Citation	Treatment	Comments
Bhattarai et al., 2005	Water	HI reported in study as ratio of lint to total biomass - recomputed here as seed plus fiber
Colaizzi et al., 2003	Control only	High lygus pressure in study - HI data here only for non-stressed treatments.
Fitzgerald et al., 2006	Tillage	High level of soil variability in field.
Mauney et al., 1994	Control only	Only considering ambient, non-stressed treatments
Ortiz et al., 2010	Nematicide	Also included different soil types
Pettigrew, 2003	Fertility	Different potassium levels.
Pettigrew, 2008	Temperature	NA
Wells and Meredith, 1982	Cultivars	Cultivar release dates between 1905 and 1978.

Methods

Objective 1

Two cotton cultivars, FiberMax 9170 B2F (FiberMax®, Bayer CropScience, Lubbock, TX) and Stoneville 5458 B2F (Stoneville®, Bayer CropScience, Lubbock, TX), were grown on a row irrigated field near Lubbock, TX for this project. A portion of each cultivar was harvested using a spindle picker (John Deere 9996, Moline, IL), a cotton stripper harvester (John Deere 7460, Moline, IL) with field cleaner (stripper w/FC), and the same cotton stripper harvester with the field cleaner bypassed (stripper NFC). During harvest of the two plots using the cotton stripper with field cleaner, a bin was attached to the chassis of the harvester to collect the material separated from the seed cotton by the field cleaner over three 46-m lengths of the field. This “bur trail” material would normally be discarded back into the field during harvest but was collected to aid in the estimation of total biomass yield. The three plots harvested within each cultivar were each 12 rows wide by approximately 236 m long (0.3 ha). Prior to machine harvest, the biomass on the ground including pre-harvest seed cotton loss and other plant parts laying on the ground surface was collected from five random locations in each plot. Each location consisted of a 3-m (10 ft.) length of plants and one adjacent furrow (i.e. the 102-cm by 3-m space between plant rows). The locations in each plot were marked after the pre-harvest biomass samples were collected so that we could return to the same locations to collect the biomass on the ground after machine harvest. After machine harvest, the plant stalks remaining on the row at each location were cut approximately 3-cm above the surface of the ground and counted and collected to estimate stalk yield (Figure 1). The biomass collected before and after harvest along with the stalks cut at each location were weighed before and after oven drying so that biomass yields could be reported on a dry-matter basis.

The machine harvested cotton was weighed in the field to determine seed cotton yield and taken to the USDA ARS Cotton Production and Processing Research Unit at Lubbock, TX for ginning. The stripper harvested cotton was processed through the following machine sequence at the gin: suction, green boll/rock trap, steady flow, #1 dryer (no heat), #1 inclined cleaner, #1 extractor cleaner (combination bur/stick machine), #2 dryer, #2 inclined cleaner, #2 extractor cleaner (3 saw stick machine), auger distributor, extractor-feeder, 93 saw gin stand, #1 saw-type lint cleaner, condenser/lint slide, and bale press. The picker harvested cotton was processed using the same machine sequence except that the #2 extractor cleaner was bypassed. Prior to ginning, five samples were collected from the seed cotton harvested from each cultivar under each harvest method for fractionation analysis (Shepherd, 1972). Seed and lint weights were recorded after ginning.

Figure 1. Cut stalks in the furrow of one 3-m length of row.

Harvest index was calculated by equation 1 using the lint, seed, and total biomass yields measured.

$$HI = \frac{Lint+Seed}{Total\ Dry\ Biomass} \qquad \text{Equation 1}$$

where:

HI = harvest index,
Lint = lint yield (kg/ha),
Seed = seed yield (kg/ha), and
Total Dry Biomass = total dry matter biomass yield (kg/ha).

Objective 2

Data from the current study described above as well as several harvesting and ginning research projects conducted over the time period from 2006 through 2011 were compiled to document the seed and foreign matter production for modern cotton cultivars produced in the Texas High Plains (Boman et al., 2011; Faulkner et al., 2011a; Keeling et al., 2011; Kelley et al. 2011; Wanjura et al., 2010; Wanjura et al., 2011a; Wanjura et al., 2011b). These studies encompassed 13 modern cultivars and three harvest methods (picker, stripper with field cleaner, and stripper without field cleaner). The experiments were conducted on 15 different farms across the Texas High Plains region. Production practices were different between farms due to variation in soil type, irrigation capacity, irrigation system design, annual rainfall depth, meteorological conditions, geographic location, and planting seed genetic technology (e.g. herbicide tolerant and/or pest resistant traits). Additionally, data were collected from commercial gins as well as the USDA ARS Ginning Laboratory at Lubbock, TX. Thus, the data are expected to be reflective of current modern production and ginning practices across the Texas High Plains.

Seed and foreign matter production data collected from each study were normalized by lint production and are reported in terms of mass per 218 kg lint bale (480 lb.). Fractionation samples were collected from the seed cotton prior to ginning and the mass per lint bale for total foreign matter, burs, sticks, and leaf and fine trash are reported.

Objective 3

A severe drought occurred across a large portion of the US cotton belt during 2011 which covered most of Texas, Oklahoma, New Mexico, and Louisiana. Pasture and hay stocks for cattle herds were quickly consumed without replacement causing producers to look to alternative feed stocks for livestock. Based on conversations with several High Plains ginners, some operations were able to sell their gin byproducts for prices in the range of $55 to $143 per Mg ($50 to $130 per ton). Additional revenue from by-product sales was most often credited back to producers to offset ginning charges. In some cases, cotton producers that also owned cattle, retained ownership of the by-product material and did not receive the ginning charge credit.

This unique situation caused many producers to question the use of field cleaners on cotton stripper harvesters because field cleaners remove a substantial portion of foreign material from harvested seed cotton that is normally transported to and removed at the gin. A simple economic model was developed to help producers determine the minimum price that a gin must credit back to the producer in order for the producer to consider bypassing the field cleaner of a cotton stripper. The model (Equations 2 - 5) balances net ginning charges (NGC) based on two different initial foreign material levels.

$$NGC_1 = NGC_2 \quad \text{Equation 2}$$

$$[Lint + Seed + Trash_1] * GGP - Trash_1 * TP = [Lint + Seed + Trash_2] * GGP - Trash_2 * TP \quad \text{Equation 3}$$

$$[Trash_2 - Trash_1] * GGP = [Trash_2 - Trash_1] * TP \quad \text{Equation 4}$$

$$GGP = TP \quad \text{Equation 5}$$

where:

NGC_i = net ginning charge ($/bale) for initial foreign matter level i (i = 1: stripper harvested with field cleaner, i = 2: stripper harvested with field cleaner bypassed)
Lint = lint weight per bale (kg/bale),
Seed = Seed weight per bale (kg/bale),
$Trash_i$ = foreign matter weight per bale for initial foreign matter level i (kg/bale),
GGP = gross ginning price ($/kg of initial seed cotton weight),
TP = trash sales price ($/kg).

Assumptions for the model include:

1. Seed and lint production (weight per bale) are equivalent across initial foreign matter levels,
2. GGP is equivalent across initial foreign matter levels and includes all charges associated with ginning and module transportation, and
3. TP is equivalent across initial foreign matter levels.

Results

Objective 1

Total cotton crop biomass yield (Figure 2), averaged across both cultivars, was 4380, 5441, and 5073 kg/ha (3906, 4852, and 4523 lb/acre) for the picker, stripper NFC, and stripper w/FC harvest methods, respectively. Since all of the biomass produced by the cotton crop was accounted for, differences by harvest method in terms of total biomass yield were not expected. Thus, we expect that the observed differences in total biomass yield are a consequence of field variability. Approximately half of the total biomass produced remained in the field after machine harvest for the picker and stripper w/FC harvest methods. Approximately 7% more total biomass was transported to the gin for the stripper NFC harvest method compared to the other two harvest methods.

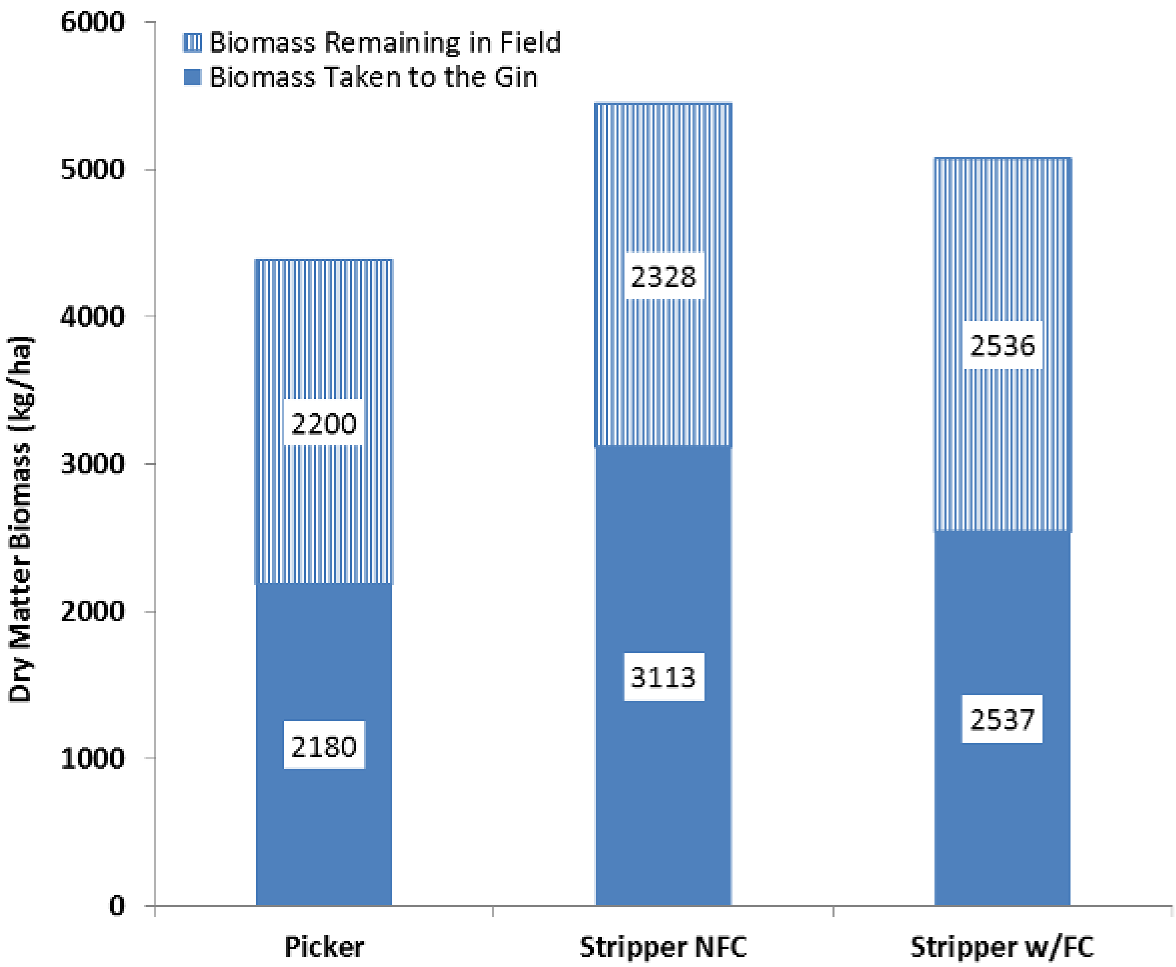

Figure 2. Total cotton crop biomass yield by harvest method averaged over two varieties.

The seed, lint, and foreign matter component contributions to the biomass yield transported to the gin averaged over both cultivars is shown in Figure 3. Lint and seed yield were about the same for the two stripper based harvesting methods and averaged 851 and 1223 kg/ha (759 and 1091 lb/acre), respectively. Lint and seed yield were slightly reduced for the picker compared to the stripper based treatments and averaged 802 and 1127 kg/ha (715 and 1005 lb/acre), respectively. Inherent differences in the design and operation of picker and stripper harvesters results in reduced harvesting efficiency for picker harvesters that often translates into lower lint and seed yields. The main factor causing the observed differences in total gin biomass among harvest methods are differences in the amount of foreign material harvested. Foreign material yield averaged 1249 kg/ha (1114 lb/acre) for the stripper NFC harvest method which was approximately double that of the stripper w/FC. The picker had the lowest foreign matter yield (391 kg/ha [349 lb/acre]) due to its selective harvesting action that targets seed cotton in mature, well opened bolls.

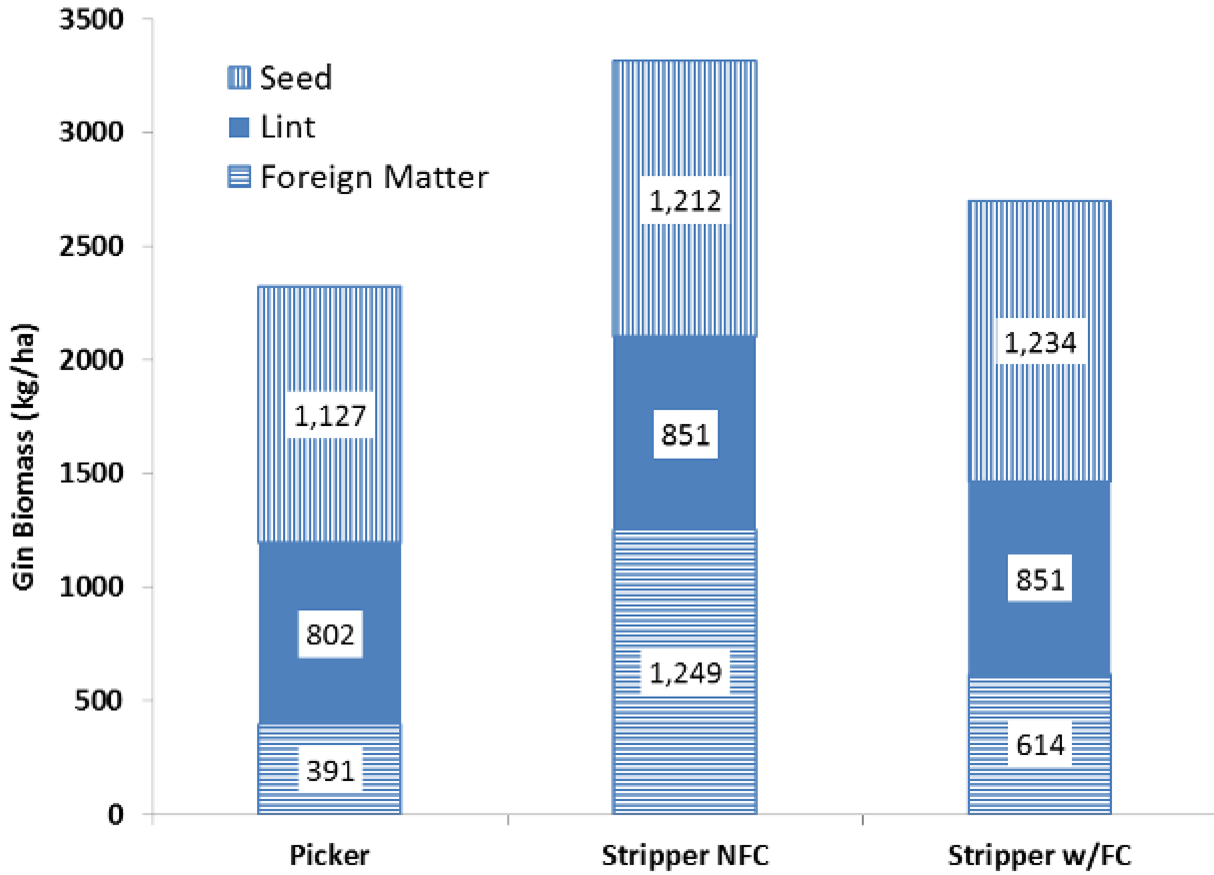

Figure 3. Seed, lint, and foreign matter contributions to the portion of total cotton crop biomass taken to the gin for post-harvest processing (averaged across two cultivars).

The biomass yield components remaining in the field after machine harvest are shown in Figure 4. Pre-harvest ground mass ranged from 1185 kg/ha (1057 lb/acre) for the picker harvested plots to 1396 kg/ha (1245 lb/acre) for the plots harvested by the stripper NFC. The pre-harvest ground mass values shown in Figure 4 are considered to be unusually high and are not considered normal. The pre-harvest ground mass was a result of pre-harvest weather events and natural shedding of vegetative material from the plants and not a result of machine/plant interaction. Analysis of the pre-harvest ground mass samples indicated that seed cotton made up about 21% of the total mass. Stalk yield was similar across harvest methods and averaged about 700 kg/ha (624 lb/acre). Stalk yield was expected to be substantially higher for the picker treatment since a smaller portion of the foreign material on the plants (especially burs and sticks) was harvested with the picked seed cotton taken to the gin. However, post-harvest ground mass was highest for the picker (319 kg/ha [284 lb/acre]) which was 75 kg/ha (67 lb/acre) more than the stripper w/FC and 119 kg/ha (106 lb. /acre) more than the stripper NFC. Increased post-harvest ground mass yield for the picker indicates that the foreign matter not contained in the picked seed cotton at the gin and not remaining on the stalks, was likely dropped on the ground as the picker harvester passed through the field. After machine harvest, seed-cotton made up 21% and 29% of the post-harvest ground mass for FM 9170 B2F and STV 5458 B2F, respectively. Total dry-matter biomass yield remaining in the field after harvest was highest for the stripper w/FC harvest method (2536 kg/ha [2262 lb/acre]) when the bur trail biomass yield of 356 kg/ha (317 lb/acre) was included.

Considering total dry biomass weight and total lint and seed weights, harvest index averaged 0.45 and 0.51 for the FiberMax 9170 B2F and Stoneville 5458 B2F cultivars, respectively. Harvest index standard deviation was 0.05 and 0.03 for FiberMax 9170 B2F and Stoneville 5458 B2F, respectively. It is important to note that harvest index calculated according to equation 1 includes the mass of all lint and seed produced by the crop and not just the portion of lint and seed production taken to the gin.

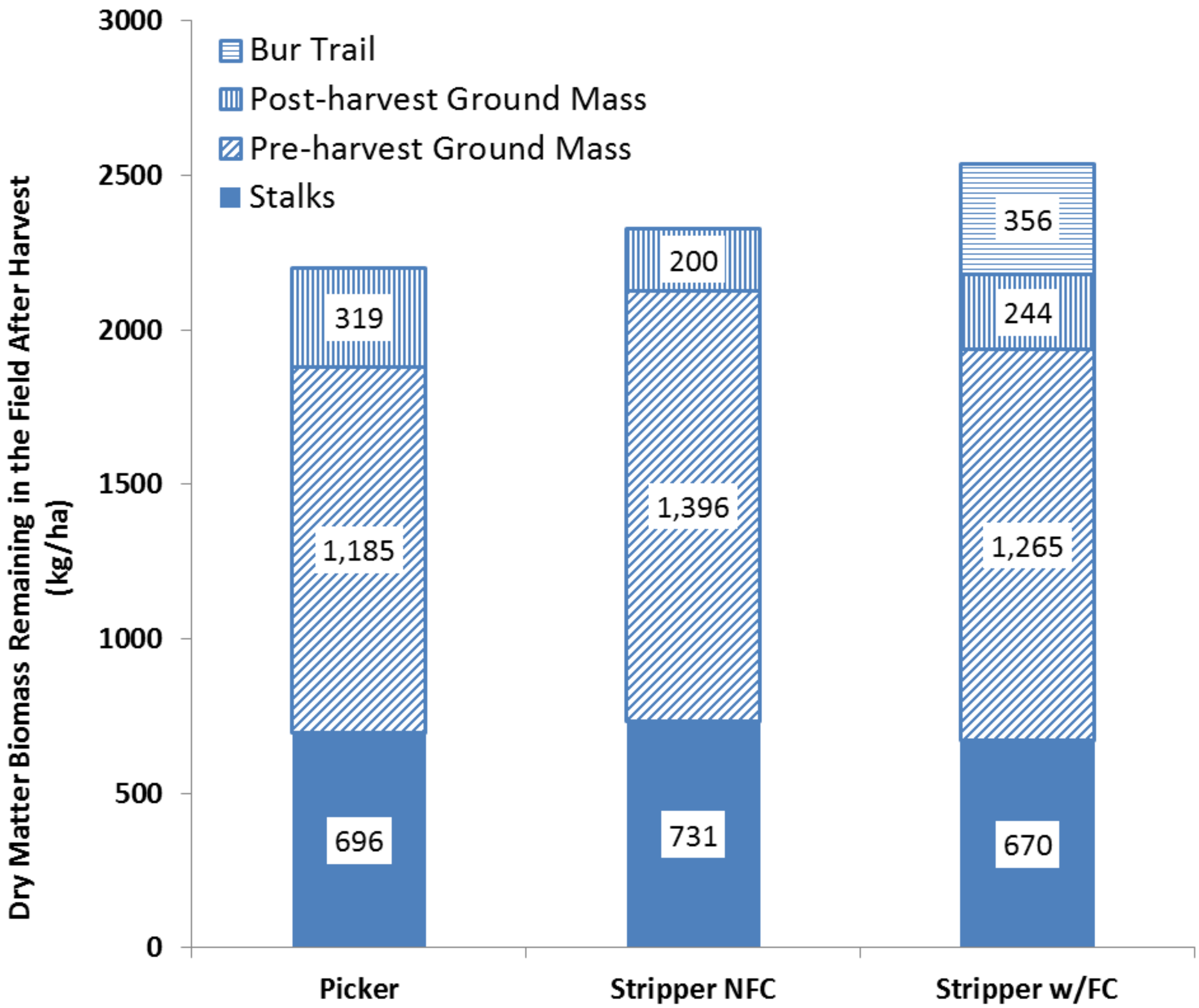

Figure 4. Components of the portion of total cotton crop biomass remaining in the field after harvest (averaged across two cultivars).

Objective 2

Lint turnout, seed weight per bale, and foreign matter component weights per bale from the seven studies discussed previously are shown in table 2. As expected, lint turnout was highest for the picker harvest method which averaged 35%. The stripper w/FC and the stripper NFC turnout values averaged about 5 and 10% less than the picker turnout, respectively. Average seed weight varied slightly across harvest methods and ranged from 341 kg/bale (750 lb/bale) for the stripper NFC to 354 kg/bale (780 lb/bale) for the stripper w/FC. Total foreign matter weights varied as expected according to lint turnout values where the picker, stripper NFC, and stripper w/FC values averaged 70, 368, and 173 kg/bale (154, 810, and 381 lb/bale), respectively. Similar foreign matter levels for machine picked and machine stripped cotton were reported by Baker et al., 1994. For the picker harvest method, combined leaf trash/fine trash/mote weight and bur weight accounted for 61% and 29% of the total foreign matter weight, respectively. Bur weight comprised 54% and 48% of the total foreign matter weight for the stripper NFC and stripper w/FC harvest methods, respectively. Combined leaf trash, fine trash, and mote weight made up 28% and

33% of the total foreign material weight for the stripper NFC and stripper w/FC harvest methods, respectively. Stick weight was 10%, 18%, and 19% of the total foreign matter weight for the picker, stripper NFC, and stripper w/FC harvest methods, respectively.

Table 2. Lint turnout, seed weight, and foreign matter component weights for three harvest methods.

		Picker (n = 26)		**Stripper NFC* (n = 7)**		**Stripper w/FC* (n = 26)**	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Lint Turnout	(%)	34.7	2.1	25.1	3.0	29.7	3.0
Seed Weight	(kg/bale)	344	25.5	341	33.5	354	32.4
Total Foreign Matter	(kg/bale)	70	22.6	368	120.6	173	61.1
Bur Weight	(kg/bale)	21	7.5	198	102.4	83	40.1
Stick Weight	(kg/bale)	7	3.3	67	51.6	32	14.6
Leaf/Fines/Motes	(kg/bale)	42	17.3	103	47.7	58	17.9

*Stripper NFC and Stripper w/FC indicate a brush-roll stripper harvester with the onboard field cleaner in bypass and through modes, respectively.

Objective 3

The economic model presented in equations 2-5 balances net ginning charges ($/bale) for a single bale of cotton harvested by two different methods, each with a different level of total foreign material (i.e. stripper w/FC and stripper NFC). The only revenue stream considered in the model is that generated from gin byproduct sales as the assumption was made that seed and lint revenue is equivalent ($/bale) across turnout levels. After reducing the model to simplest terms (equation 5), the minimum trash sales price required to cover additional ginning costs associated with bringing additional byproduct material to the gin is equivalent to the gross ginning price (Table 3). In other words, under the conditions specified in the economic model presented, a producer does not realize any economic benefit from turning off the field cleaner on their cotton stripper harvester unless the gin credit for "trash" is equivalent to or greater than the gross ginning price. Model results indicate that the break even trash price is independent of lint turnout and dependent only on gross ginning price. Decreased lint value for seed cotton containing higher amounts of initial foreign matter has been documented (Faulkner et al., 2011b). The economic model presented does not account for decreases in lint value associated with harvest methods which also have higher initial foreign matter content. Also not considered by the model is the additional time that would be required to handle the additional material generated in the field when a stripper field cleaner is bypassed compared to when it is used. Additional material handling time translates into reduced harvest productivity and increased harvest cost per bale.

Table 3. Break-even trash price and net ginning expense over a range of gross ginning prices.

Gross Ginning Price (GGP)		Break Even Trash Price (TP)		Net Ginning Expense After Trash Sales
($/kg)	($/cwt.)	($/kg)	($/ton)	($/bale)
$0.044	$2.00	$0.044	$40.00	$24.60
$0.050	$2.25	$0.050	$45.00	$27.68
$0.055	$2.50	$0.055	$50.00	$30.75
$0.061	$2.75	$0.061	$55.00	$33.83
$0.066	$3.00	$0.066	$60.00	$36.90
$0.072	$3.25	$0.072	$65.00	$39.98
$0.077	$3.50	$0.077	$70.00	$43.05
$0.083	$3.75	$0.083	$75.00	$46.13
$0.088	$4.00	$0.088	$80.00	$49.20
$0.094	$4.25	$0.094	$85.00	$52.28
$0.099	$4.50	$0.099	$90.00	$55.35
$0.105	$4.75	$0.105	$95.00	$58.43
$0.110	$5.00	$0.110	$100.00	$61.50

Conclusions

The findings of this work are:

- Approximately 2200 – 2500 kg/ha or half of the total biomass produced by two modern cultivars under irrigated conditions remained in the field after machine harvest with a picker or brush roll stripper with field cleaner. The portion of total biomass remaining in the field was reduced to 43% when a brush roll stripper without field cleaner was used.
- Harvest index measured for the two cultivars used in this study were within the range of published harvest index values. Harvest index averaged 0.45 and 0.51 for FiberMax 9170 B2F and STV 5458 B2F, respectively.
- Lint turnout for cotton harvested using a picker, stripper with field cleaner, and stripper without field cleaner averaged 35%, 30%, and 25%, respectively for seven recent cotton harvesting and ginning studies. These turnout values were measured for modern cotton cultivars grown under production conditions typical to the Southern High Plains of the US. Seed and foreign matter content measured during the same studies followed similar trends by harvest method seen in earlier studies.
- Revenue from the sale of gin byproducts at any price can help offset ginning expenses. However, producers should consider the gin trash sales price and the gross ginning price prior to making a decision to bypass the field cleaner on a cotton stripper. If the trash sales price (or the credit for gin trash from the gin) is less than the gross ginning price, producers should not consider bypassing the field cleaner on a cotton stripper. If the trash sales price is equal to or greater than the gross ginning price, producers may realize an economic benefit by bringing additional foreign material to the gin (i.e. bypassing a cotton stripper field cleaner). However, producers should also consider potential decreases in lint value and harvest productivity prior to deciding to bypass the field cleaner on a cotton stripper.

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Disclaimer

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References

Aquino, F.L., J.R. Hernandez, and S.C. Capareda. 2007. Elucidating the Solid, Liquid and Gaseous Products form Pyrolysis of Cotton Gin Trash. ASABE Paper No. 076083. St. Joseph, Mich.: ASABE.

Baker, R.V., W.S. Anthony, and R.M. Sutton. 1994. Seed cotton cleaning and extracting. p. 69-90. *In* W.S. Anthony and W.D. Mayfield (eds.) Cotton Ginners Handbook. Agricultural Handbook No. 503. U.S. Dept. of Agric. Washington D.C.

Bhattarai, S. P. , A. D. McHugh, G. Lotx and D. J. Midmore. 2005. The response of cotton to subsurface drip and furrow irrigation in a Vertisol. Expl. Agric. 42:29–49.

Boman, R.K., J.D. Wanjura, M.S. Kelley, C.W. Ashbrook, E.F. Hequet. 2011. Picker vs. Stripper Harvesting in the Texas High Plains: Agronomic Implications. In Proc. 2011 Beltwide Cotton Conferences. Available on CDROM, pp. 507 - 509. Memphis, TN: National Cotton Council.

Colaizzi, P. D., E. M. Barnes, T.R. Clarke, C.Y. Choi, and P.M. Waller. 2003. Estimating soil moisture under low frequency irrigation using the CWSI. ASCE J. of Irrigation and Drainage Engineering 129:27-35.

Faulkner, W.B., J.D. Wanjura, R.K. Boman, B.W. Shaw, C.B. Parnell, Jr. 2011a. Evaluation of Modern Cotton Harvest Systems on Irrigated Cotton: Harvester Performance. *Applied Eng. in Agric.* 27(4): 497 – 506.

Faulkner, W.B., J.D. Wanjura, E.F. Hequet, R.K. Boman, B.W. Shaw, C.B. Parnell, Jr. 2011b. Evaluation of Modern Cotton Harvest Systems on Irrigated Cotton: Fiber Quality. *Applied Eng. in Agric.* 27(4): 507 - 513.

Fitzgerald, G. J., S. M. Lesch, E. M. Barnes, W. E. Luckett. 2006. Directed sampling using remote sensing with a response surface sampling design for site-specific agriculture. Computers and Electronics in Agriculture 53:98–112.

Holt, G. A., G. L. Barker, R. V. Baker, A. Brashears. 2000. Characterization of Cotton Gin Byproducts Produced by Various Machinery Groups Used in the Ginning Operation. Transactions of the ASAE 43(6): 1393-1400.

Holt, G.A., J.L. Simonton, M.G. Beruvides, and A.M. Canto. 2003. Feasibility Study for Constructing and Operating a Facility to Manufacture Fuel Pellets from Cotton By- Products. ASAE Paper No. 031165. St. Joseph, Mich.: ASAE.

Keeling, J.W., R.K. Boman, J. Bordovsky, J.D. Wanjura. 2011. Effects of SDI Irrigation Level, Nitrogen Rate, and Harvest Method on Cotton Yield and Fiber Quality at AG-CARES, Lamesa, TX, 2010. In AG-CARES 2010 Annual Report. Texas AgriLife Research Service Technical Report 11-1. College Station, TX: Texas AgriLife Research Service.

Kelley, M.S., J.D. Wanjura, R.K. Boman, C. Ashbrook. 2011. Harvest Timing and Techniques to Optimize Fiber Quality in the Texas High Plains. In Proc. 2011 Beltwide Cotton Conferences. Available on CDROM, pp. 449 - 454. Memphis, TN: National Cotton Council.

Luke-Morgan, A., G. Shumaker, and J. McKissick. 2008. The Impact on Georgia Biomass for Feedstock from Rising Input and Transportation Costs in 2008. The University of Georgia, Center for Agribusiness and Economic Development, College of Agricultural and Environmental Sciences. CR-08-10. 18 pp.

Mauney, J. R., Kimball, B. A., Pinter, P. J., Jr., LaMorte, R. L., Lewin, K. F., Nagy, J., and Hendrey, G. R. (1994). Growth and yield of cotton in response to a free-air carbon dioxide enrichment (FACE) environment. Agric. For. Meteorol. 70, 49–68.

Nalley, L., M. Popp, K. Brye, M. Matlock. 2011. How Potential Carbon Policies Could Affect Cotton Location and Production Practices in the United States" Forthcoming in the Journal Agriculture and Resource Economics.

Pettigrew, T.W. 2003. Relationships between Insufficient Potassium and Crop Maturity in Cotton. Agron. J. 95:1323–1329.

Pettigrew, T.W. 2008. The Effect of Higher Temperatures on Cotton Lint Yield Production and Fiber Quality. Crop Sci. 48:278–285.

Shepherd, J.V. 1972. Standard Procedures for Foreign Matter and Moisture Analytical Tests Used in Cotton Ginning Research. Agricultural Handbook No. 422. Washington D.C.: USDA-ARS.

Wanjura, J.D., M.S. Kelley, R.K. Boman, G.A. Holt. 2010. Harvesting to Optimize Fiber Quality. ASABE Paper No: 1009229. St. Joseph, MI: ASABE.

Wanjura, J.D., G.R. Gamble, G.A. Holt, M.G. Pelletier. 2011a. Influence of Grid Bar Shape on Field Cleaner Performance - Field Testing. Submitted for review/publication in Journal of Cotton Science (August 8, 2011).

Wanjura, J.D., W.B. Faulkner, G.A. Holt, M.G. Pelletier. 2011b. Influence of Seed Cotton Extractor Cleaners and Cleaning Rate on Gin Turnout and Fiber Quality. 2011. ASABE Paper No. 1111287. St. Joseph, MI: ASABE.

Wells, R. and W.R. Meredith. 1982. Comparative Growth of Obsolete and Modern Cotton Cultivars. I. Vegetative Dry Matter Partitioning. Crop Science 24:858-862.

Youngquist, A., M. Krzysik, B. W. English, H. N. Spelter, P. Chow. 1996. Agricultural Fibers for Use in Building Components. *In:* The use of recycled wood and paper in building applications: Proceedings of a 1996 symposium sponsored by the U.S. Department of Agriculture Forest Service, Forest Products Laboratory and the Forest Products Society, in cooperation with the National Association of Home Builders Research Center, the American Forest & Paper Association, the center for Resourceful Building Technology, and Environmental Building News. Proc. 7286. Madison, WI: Forest Products Society: 123-134; 1996.