CULTIVAR DIFFERENCES IN FIBER-SEED ATTACHMENT FORCE: MEASUREMENT TECHNIQUES

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Abstract

Cotton cultivars are well known to differ in yield and fiber quality and they also differ in how strongly fibers are attached to seed. Cultivars with reduced fiber-seed attachment force have the potential to be ginned faster with less energy and less fiber damage given that all other properties are the same. The overall objective of this project was to develop cultivars with improved "ginning efficiency", while preserving yield and fiber quality. Improved ginning efficiency as defined in this study included both reduced net gin stand energy usage (that above idling) and increased ginning rate. Initial results for 46 cultivars, including 6 semi-naked seeded cultivars, ginned on a 10-saw gin stand showed significant variation in net gin stand energy usage, ginning rate, and other fiber properties. The specific objective of this paper was to determine how these properties related to fiber-seed attachment force measured with a pendulum-type tester. A sub-set of the 46 cultivars, including 15 total cultivars (2 semi-naked seeded cultivars), was tested in this experiment which included a wide range of net gin stand energy (7.5 to 12.0 Wh/kg lint) and ginning rate (2.5 to 3.3 g lint/sec). Approximately 45 seeds were tested per cultivar and fiber-seed attachment force was measured for two tufts of fiber on each side of the seed (four tufts per seed), with two tufts oriented towards the chalazel (rounded) end of the seed and two tufts oriented towards the micropyle (pointed) end of the seed. Fiber-seed attachment force was found to vary statistically among cultivars ranging from 30 to 47 cN*cm/mg fiber when averaged over seed ends. A significant positive correlation was found between fiber-seed attachment force and net gin stand energy verifying the assumption that cultivar differences in net gin stand energy were largely related to differences in fiber-seed attachment force. Both fiber-seed attachment force and net gin stand energy were slightly (statistically insignificant) negatively correlated with ginning rate hinting that cultivars with low fiber-seed attachment force ginned faster. It was suspected that the trends were masked by ginning small samples on the 10-saw gin. Fiber-seed attachment force and net gin stand energy both increased significantly with ginned seed fuzz (% by weight) and the number of AFIS seed coat neps (SCN). These results suggested that seed fuzz levels are an indicator of fiber-seed attachment force and that increased fiber-seed attachment force resulted in seed coat fragmentation. Net gin stand energy was positively correlated with fiber length and strength and negatively correlated with fiber fineness, but these properties were not correlated with fiber-seed attachment force. Future studies may measure net gin stand energy consumption to indicate relative differences in fiber-seed attachment force among cultivars, but the effects of fiber length, strength, and fineness should be considered in the interpretation of results. Further study is needed to interpret ginning rate measured on a 10-saw gin stand.

Introduction

During saw-type cotton ginning, gin stand saws separates fiber from seed which are retained in the seed roll by ginning ribs, eventually moving out of the seed roll in a stream separate from lint. Most fibers tend to be ginned (removed or broken) without additional breakage due to a weakened area in the fiber at the surface of the seed. Anthony and Griffin (2001) showed that the force required to break an individual fiber equals 1.8 times the force required to remove it from the seed. The gin stand is known to break some fibers in multiple places or with fragments of fiber left on the seed, this leads to reduced fiber length and increased short fiber content. Increased neps (fiber entanglement) are also attributed to the gin stand. Long fiber, low short fiber content, and low nep content are desirable qualities for spinning fiber into yarn, so it is important to avoid excessive breakage and other damage caused by the gin stand.

Cotton cultivars are well known to differ in yield and fiber quality. Cultivars also differ in how strongly fibers are attached to seed (Fransen et al., 1984, Verschraege and Kiekens, 1987; and Porter and Wahaba, 1999). Also, gin stand energy consumption has been shown to differ among cultivars (Anthony et al., 1982; Boykin, 2007; and Bechere et al., 2011) with differences presumably related to fiber-seed attachment force. Cultivars with reduced fiber-seed attachment force have the potential to be ginned faster with less energy (reducing the electrical costs required to operate the gin stand) and less fiber damage, given that all other properties are the same. The overall objective of this project was to develop cultivars with improved "ginning efficiency", while preserving yield and fiber quality. Improved ginning efficiency, as defined in this study, included both reduced net gin stand energy usage (that above idling) and increased ginning rate. Initial results for 46 cultivars, including 6 semi-naked seeded cultivars, ginned on a 10-saw gin stand showed significant variation in net gin stand energy usage, ginning rate, and other fiber properties (Bechere et al., 2011); so the specific objective of this paper was to determine how these properties related to fiber-seed attachment force measured with a pendulum-type tester.

Materials and Methods

A sub-set of the 46 cultivars, including 15 total cultivars (2 semi-naked seeded cultivars), was tested in this experiment which included a wide range of net gin stand energy (7.5 to 12.0 Wh/kg lint) and ginning rate (2.5 to 3.3 g lint/sec) as shown in table 1. The two semi-naked seeded cultivars were SC9023ns57-13-5-1 and AR9317-26 and table 1 shows that these cultivars required the least gin stand energy.

Table 1. Net gin stand energy and ginning rate for cultivars processed on a 10-saw lab gin (Bechere et al., 2011).

Cultivar	Net gin stand energy, Wh/kg lint	Ginning rate, g lint/sec
TAM182-34-ELS	12.0	3.11
PHY72	11.8	2.72
STV4554B2RF	10.6	2.54
ST474	10.6	2.97
FM832	10.5	3.15
JJ1145ne	10.3	3.12
MD15OP(MD15)	10.0	3.21
DP555BR	9.9	2.96
TAM98-99ne	9.8	3.02
SG747	9.7	3.02
FM960B2R	9.6	3.32
STV5599BR	9.3	3.18
AR9608-08-03ne	9.1	2.84
SC9023ns57-13-2-1	9.0	2.89
AR9317-26	7.5	3.09
LSD	0.4	0.37

For analysis of fiber-seed attachment force, these cultivars were grown and hand-picked from one field in 2009, with two replications per cultivar. Approximately 45 seeds were tested per cultivar and fiber-seed attachment force was measured for two tufts of fiber on each side of the seed (four tufts per seed), two tufts oriented towards the chalazel (rounded) end of the seed, and two tufts oriented towards the micropyle (pointed) end of the seed. For this report, tuft preparation was minimal to eliminate any potential bias due to combing. Additional samples were analyzed by combing tufts to align fibers before testing and trimming fibers to 1.2 cm (the width of the fiber clamp) to standardize fiber length before weighing, but these results were not available for this report.

Fiber-seed attachment force was measured with a modified SDL2 Cotton Seed Attachment Tester (Shirley Developments Limited, Didsbury, Manchester, England). To measure fiber-seed attachment force, a pendulum was raised and locked into position with a known amount of potential energy (figure 1). A cartridge was placed in the path of the pendulum which held the seed in place behind a slotted plate on one side of the pendulum path and the tuft of fibers retained by clamps on the alternate side of the pendulum path (figure 2). The pendulum was released to pass through the fiber bundle between the seed plate and fiber clamp, thus shearing the tuft of fiber from the seed. Data were deleted if the bundle was not sheared by the pendulum or if a portion of the fiber bundle remained on the seed. The instrument was modified with an inclinometer and computer to measure and record the peak position (angle) of the pendulum swing after shearing ("sample peak position"). Blanks were also run without sample to measure the peak position (angle) of the pendulum blank ("blank peak position"). The difference in the "blank peak position" and "sample peak position" was used to calculate the fraction of energy removed from the pendulum swing. This was multiplied by the potential energy of the pendulum to determine the energy required to shear the fiber bundle from the seed. The fiber bundle was weighed and the fiber-seed attachment force (cN*cm/mg fiber) was standardized by dividing the energy for shearing the bundle (cN*cm) by the fiber weight (mg fiber).

Figure 1. Fiber-seed attachment force tester just before releasing the pendulum. Pendulum arm locked in raised position and sample cartridge in place. Note the prepared seed with four bundles in the lower portion of the picture.

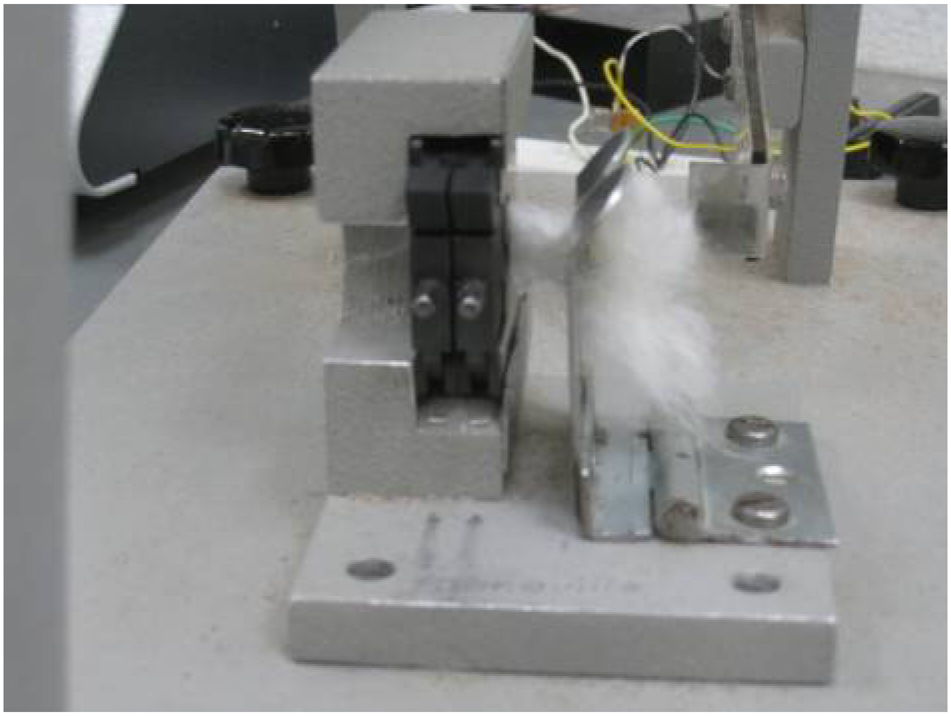

Figure 2. Sample cartridge holding seed behind slotted seed plate and fiber bundle in clamps.

Results and Discussion

Overall, fiber-seed attachment force was found to vary statistically among cultivars ranging from 30 to 47 cN*cm/mg fiber (tables 2 and 3). Averaged over cultivars, fiber-seed attachment force was less on the side of the seed towards the chalazel end of the seed (29 cN*cm/mg fiber) than towards the micropyle end of the seed (50 cN*cm/mg fiber) with p value < 0.0001 (tables 2 and 3). Also, statistical differences among cultivars were stronger towards the chalazel end (p value = 0.0002, table 3) than towards the micropyle end (p value = 0.0359, table 3). The p value for the interaction between tuft location and cultivar was 0.0080 (table 2), so relative differences in cultivars were significantly different for some cultivars when measurements were made toward opposite ends of the seed.

Table 2. Statistics for cultivar differences in fiber-seed attachment force measured on the side of the seed towards the chalazel and micropyle seed ends.

Effect	DF	F value	P value
Rep	**1**	**3.27**	**0.0923**
Cultivar	**14**	**4.35**	**0.0049**
Seed end	**1**	**1224.25**	**<0.0001**
Cultivar*end	**14**	**3.97**	**0.0080**

Table 3. Least square means for fiber-seed attachment force (cN*cm/mg fiber) measured on the side of the seed towards the chalazel and micropyle seed ends as well as averaged over seed ends (overall). Cultivars sorted by overall attachment force.

Cultivar	Chalazel	Micropyle	Overall
PHY72	37.1 G[Z]	59.6 A	47.0 A
ST474	35.3 GH	56.5 A	44.7 AB
STV4554B2RF	34.9 GIH	53.0 CDAB	43.0 ABC
JJ1145ne	32.8 GIHJ	53.7 CAB	42.0 ABC
TAM182-34-ELS	29.4 KIHJ	57.5 A	41.1 ABC
SG747	31.5 GIHJ	49.7 CDAB	39.6 ABCD
TAM98-99ne	27.3 KJ	55.8 AB	39.0 ABCDE
MD15OP(MD15)	27.8 KJ	51.2 CDAB	37.7 BCDE
FM832	27.8 KJ	48.4 CDAB	36.7 FBCDE
FM960B2R	28.7 KIHJ	44.7 CD	35.8 FGCDE
STV5599BR	28.2 KIJ	44.1 CD	35.3 FGCDE
DP555BR	24.3 KL	44.9 CDB	33.0 FGDE
SC9023ns57-13-2-1	23.9 KLM	42.7 D	32.0 FGE
AR9608-08-03ne	21.4 LM	42.7 D	30.2 FG
AR9317-26	19.6 M	45.0 CDB	29.7 G
Mean	29	50	38

[Z] Values with same letter within a column not significantly different.

A significant and positive correlation was found between fiber-seed attachment force measured towards the chalazel and micropyle ends of the seed (table 4 and figure 3). Gin stand energy was positively correlated with fiber-seed attachment force measured towards both ends of the seed (table 4 and figure 4), but the correlation was even greater when fiber-seed attachment force was averaged over seed ends (table 4 and figure 5). This verified the assumption that cultivar differences in net gin stand energy were largely related to differences in fiber-seed attachment force. Figure 5 also notes cultivars with the lowest and highest gin stand energy, AR9317-26 and TAM182-34-ELS, respectively. AR9317-26 was the semi-naked seeded cultivar with the lowest seed fuzz percent, and TAM182-34-ELS stood out as having the longest, finest fibers and the highest number of seed coat neps. These properties as well as others were published by Bechere et al. (2011). Both fiber-seed attachment force and net gin stand energy were slightly (statistically insignificant) negatively correlated with ginning rate (table 4), but it was suspected that the trends were masked by ginning small samples on the 10-saw gin. This relationship hints that that cultivars with low fiber-seed attachment force would likely gin faster in a commercial gin, but this relationship needs to be validated by additional testing. Fiber-seed attachment force and net gin stand energy both increased significantly with ginned seed fuzz (% by weight, cultivar data not shown) and the number of AFIS seed coat neps (SCN, cultivar data not shown). These results suggested that seed fuzz levels are an indicator of fiber-seed attachment force and that increased fiber-seed attachment force resulted in seed coat fragmentation. Also, the number of bundles producing a seed coat fragment (SCF) per 100 seed noted during fiber-seed attachment testing (cultivar data not shown) was positively correlated with fiber-seed attachment force and net gin stand energy. These SCF were predominantly produced with bundles removed towards the chalazel seed end. One very important finding was that net gin stand energy was positively correlated with fiber length and strength and negatively correlated with fiber fineness (cultivar data not shown), but these properties were not correlated with fiber-seed attachment force. Therefore, additional cultivar variability in net gin stand energy exists and should be considered when evaluating cultivar differences in fiber-seed attachment force as indicated by net gin stand energy.

Table 4. Pearson correlations (r) between cultivar properties (n=15). Values followed by “**” significant at p<0.01 and “*” significant at p<0.05. Values followed by “x” indicate correlations which were significant and in the same direction (+/-) in the overall study of 45 cultivars by Bechere et al. (2011).

	Chalazel, cN*cm/mg fiber	Micropyle, cN*cm/mg fiber	Overall, cN*cm/mg fiber	Net gin stand energy, Wh/kg lint	Ginning rate, g lint/sec
Chalazel	1	0.76**	0.96**	0.76**	-0.29
Micropyle	0.76**	1	0.91**	0.78**	-0.23
Overall, cN*cm/mg fiber	0.96**	0.91**	1	0.82**	-0.28
SCF/100 seed	0.63*	0.78**	0.74**	0.65**	-0.06
Net gin stand energy	0.76**	0.78**	0.82**	1	-0.23
Ginning rate	-0.29	-0.23	-0.28	-0.23	1
Ginned seed fuzz %	0.74**	0.49	0.69**	0.63*	-0.37x
Seed index	0.22	0.32	0.27	0.33	0.47x
Lint %	0.19	-0.11	0.08	0.03	-0.11
Fibers / seed	0.57*	0.18	0.45	0.41	0.38x
Fibers / mm^2 seed	0.16	-0.18	0.03	0.04	-0.20
AFIS^Z UQLw^X	0.00	0.31	0.13	0.54*	0.37x
AFIS SFCw^W	0.15	-0.29	-0.03	-0.06	-0.22x
HVI^Y strength	0.06	0.28	0.16	0.45x	0.28x
HVI micronaire	-0.08	-0.15	-0.12	-0.43	-0.14
AFIS fineness	-0.10	-0.15	-0.13	-0.51x	0.00
AFIS IFC	0.06	-0.18	-0.04	-0.07	-0.28
AFIS maturity ratio	-0.08	0.13	0.01	0.24	0.39x
AFIS nep count	0.19	0.14	0.17	0.15	-0.65**
AFIS seed coat nep count	0.58*	0.80**	0.70**	0.82**	-0.13

^{Z} Advanced fiber information system. ^{Y} High Volume instrument. ^{X} Upper quartile length by weight.
^{W} Short fiber content by weight.

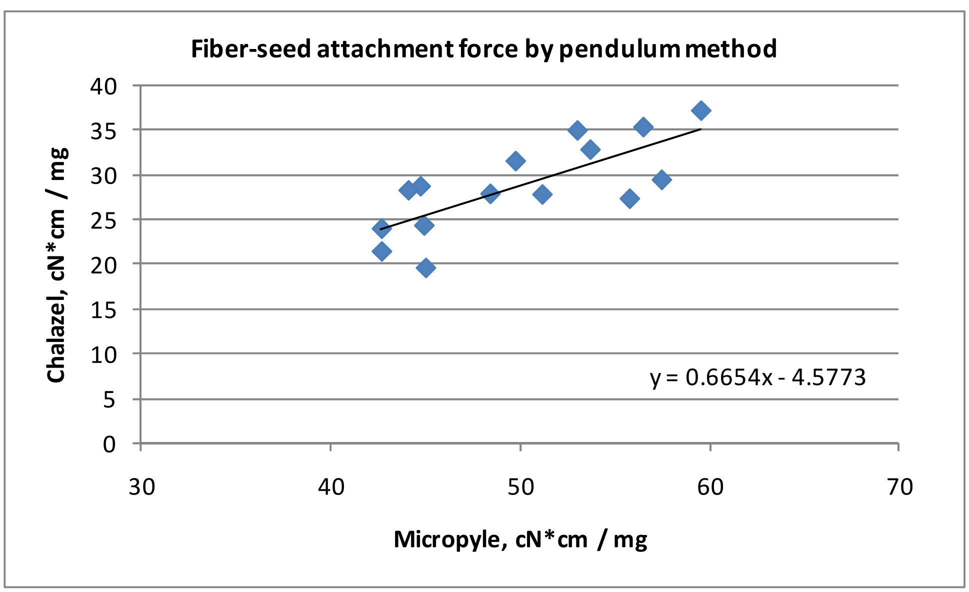

Figure 3. Fiber-seed attachment force measured towards the chalazel and micropyle ends of the seed.

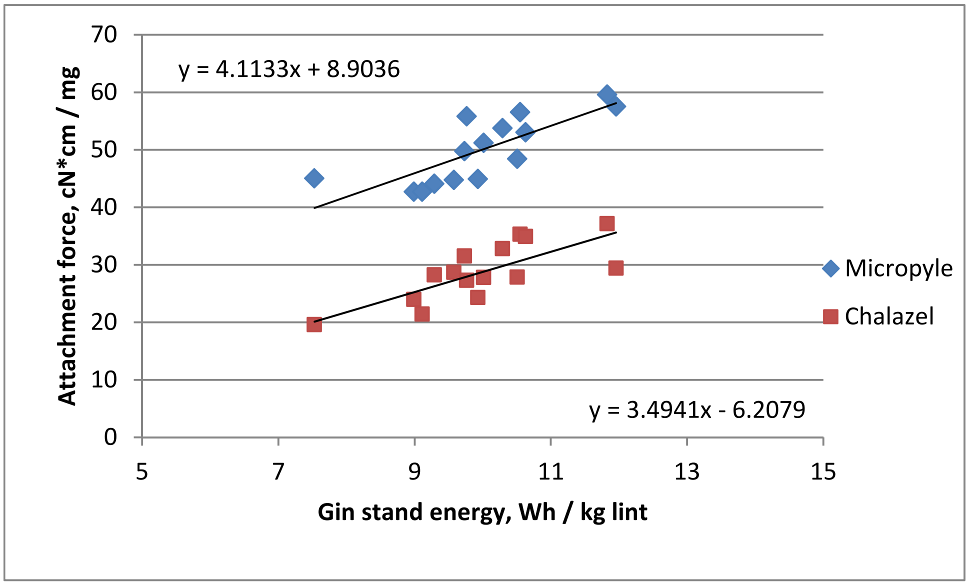

Figure 4. Relationship of gin stand energy to fiber-seed attachment force measured towards both ends of the seed.

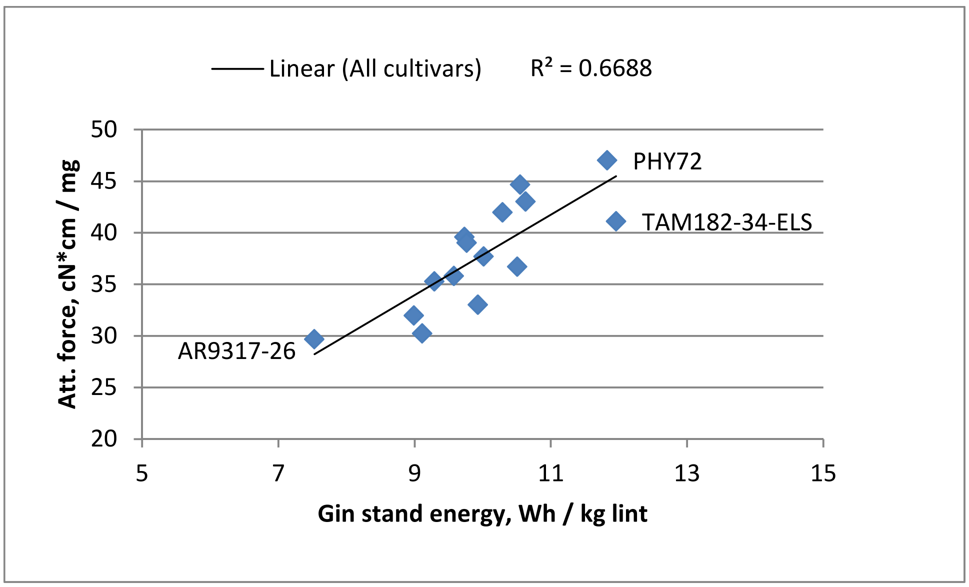

Figure 5. Relationship of gin stand energy to mean fiber-seed attachment force averaged over chalazel and micropyle seed ends.

Summary

This project was begun to improve cultivar ginning efficiency as defined as both reduced net gin stand energy usage and increased ginning rate. As this study progressed, there was a need to validate the assumption that these properties were related to fiber-seed attachment force. Net gin stand energy was strongly and positively correlated with fiber-seed attachment force, as measured by a pendulum type tester, thus validating that assumption. The correlation between ginning rate and fiber-seed attachment force was negative but statistically insignificant, possibly due to the small sample size available for processing on the 10-saw gin. Logic tells us this negative trend does exist; if a cultivar tends to gin with a reduced electrical load on the gin stand, that cultivar should gin faster. This relationship will need to be proved in future testing involving larger samples and conventional type machinery. In conclusion, future studies may measure net gin stand energy consumption to indicate relative differences in fiber-seed attachment force among cultivars, but the effects of fiber length, strength, and fineness should be considered in the interpretation of results.

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References

Anthony, W.S., and A.C. Griffin, Jr. 2001. Fiber breakage at cotton gins: causes and solutions. *Proc. Beltwide Cotton Conf.*, Anaheim, CA 9-13 Jan. 1347-1357.

Anthony, W.S., R.A. Wesley, and L.G. Brown. 1982. Dynamic programming model of a cotton ginning system. *Trans. ASAE.* 25(1):179-186,192.

Bechere, E., J.C. Boykin, and W.R. Meredith. 2011. Evaluation of cotton genotypes for ginning energy and ginning rate. *Journal of Cotton Science*. (pending publication).

Boykin, J.C. 2007. Cultivar differences in gin stand energy utilization. *Trans. ASABE*. 50(3): 733-743.

Franses, T., L. Verschraege, and P. Kalisa. 1984. Measuring cotton fiber to seed attachment force. *Cot. Fib. Trop.* 39:137-143.

Porter, M.A. and F.T. Wahba. 1999. Assessing ginnability of Australian cotton fiber. *Trans. ASAE*. 42(4):853-857.

Verschraege, L. and P. Kiekens. 1987. Cotton fiber-to-seed attachment forces. *Cotton Fibers: Their Development and Properties (2)*. Technical Monograph of the Belgian Cotton Research Group. International Institute for Cotton, Manchester, U.K. 2-5.