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BREEDING AND GENETICS

Seed Size, Ginning Rate, and Net Ginning Energy Requirement in Upland Cotton (*Gossypium hirsutum* L.)

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ABSTRACT

Nine diverse Upland cotton cultivars and germplasm lines differing in seed size were planted at two locations at Stoneville, MS in 2015, 2016, and 2017. 'AR 9317-26' and 'DP 555 BG/RR' were classified as small with a seed index (SI) < 10 g. 'FM 832', 'FM 966', and 'MD 15' had SI ranging from 10 to 12 g and were classified as intermediate seed size. 'TAM 182-34 ELS' and three other breeding lines: '201-2', '107-1', and '152-1' had large seeds with SI > 12 g. The seeds were planted in three replications at two sites at Stoneville, MS. Data were collected on ginning energy requirement (Wh kg^{-1} lint), ginning rate (g lint s^{-1}), and other agronomic and quality traits. The objectives of the test were to determine the effect of seed size on the above parameters. Statistical analyses were performed using Proc GLM. Simple Pearson's correlation tests and regression analyses were conducted to test the relationships between SI and these traits. Covariance estimates were calculated using Proc GLIMMIX to determine the direction of linear relationships. Differences in SI were highly significant among cultivars. SI was positively and significantly correlated with ginning rate but significantly and negatively correlated with ginning energy requirement. Significant and negative relationships were observed between SI and fiber uniformity, lint yield, lint turnout, and number of seeds per kg. Significant and positive relationships were observed between SI and fiber strength, fuzz percentage, and seed surface area. Relationships among SI and micronaire, fineness, and fiber length were minor.

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Differences in ginning performance of several seed cottons were described as early as 1879 by Watson (1879), who measured the time and energy consumed in ginning for a number of different cottons. He concluded that the differences among cottons in power consumption during ginning were associated with differences in the strength of the attachment of the fibers to the seed and degree of fuzziness of the seeds. Watson further reported that ginning performance and efficiency were affected by the ginning machine and the characteristics of the seed being processed. For example, the time required for ginning was affected by fuzz percentage, lint percentage, and seed size, in that order. Whereas net ginning energy depended on lint percentage, amount of fuzz, and seed size, respectively. Watson implied that large, fuzzy seeds remained in the seed roll longer and retarded the action of the gin saw.

Federow (1933) considered strength of fiber attachment to the seed coat as one of the principal factors affecting the differences in power required to gin seed cotton. His analyses indicated that the number of fibers per pound of lint and the percentage of lint could affect the time and energy consumed in ginning. However, Federow did not report on the relationship of seed size to these traits.

Smith et al. (1943) suggested that removal of the lint fibers from cotton seeds by a gin saw was affected by the properties of the seed cotton processed. Varietal characteristics could influence the time and energy required to gin seed cotton. The larger and more fuzzy-seeded cottons required more time and energy to gin than the smaller and less fuzzy-seeded cultivars. The order of influence of the three seed cotton properties on ginning rate was (1) fuzz percentage, (2) lint percentage, and (3) seed size and on net ginning energy the order was (1) lint percentage, (2) fuzz percentage, and (3) seed size.

Boykin (2007) studied gin energy use in a small-scale continuous-flow gin. He found a strong positive correlation between ginning energy and fuzz percentage. Although no significant relationship existed between seed index (SI) alone and ginning energy, SI was a significant factor for predicting ginning energy, but inversely related when added to the regression model containing fuzz percentage.

Boykin et al. (2012) found that fiber-seed attachment force varied among genotypes from 36 cN*cm/mg fiber for ‘AR9317-26’ to 64 cN*cm/mg fiber for ‘Phytogen 72’. AR9317-26 also consumed the least net gin energy. The ginning energy, ginning rate, and fiber-seed attachment force measurements differed significantly among genotypes; however, genotype differences in ginning rate determined on a lab-scale gin stand were not strongly related to fiber-seed attachment force. The authors also reported that the fiber density (number of fibers per mm^2) was not significantly related to fiber-seed attachment force or ginning energy. Fiber-seed attachment force and net ginning energy increased with AFIS (Advanced Fiber Information System) seed coat nep size and count, indicating that reduced seed coat fragmentation in lint (as well as reduced seed damage) can be achieved by breeding for reduced fiber-seed attachment force (or net gin-stand energy).

Large-seeded crop plants, in general, tend to produce plants with vigorous growth that are better able to compete for natural resources than small-seeded species (Coomes and Grubb, 2003; Muller-Landau, 2012). Ching (1973) observed positive associations between seed size, adenosine triphosphate (ATP) content per seed, and seedling vigor in ryegrass, rapeseed, and clover. In cotton, large, high-density seeds produced plants with greater seedling vigor than small low-density seeds (Kreig and Kreig, 1975; Leffler and Williams, 1983).

Pahlavani et al. (2009) reported that oil content, germination, and emergence of cotton seed were largely affected by seed size in cotton. However, they noted there was no significant relationship between seed size and protein content of seed. Snider et al. (2014) stated that it is generally accepted that large-seeded species produce more competitive seedlings that are larger, have deeper root systems, can utilize natural resources more effectively, and withstand environmental stresses better than smaller-seeded species. Snider et al. (2016) reported that seed size was negatively associated with lint yield. Edmisten (2015), however, noted that growers typically desire smaller seed because of the increased number of seeds per pound although it is generally believed that larger seeds have a perceived increase in seed vigor. The reality is that growers do not sacrifice yield for vigor. According to Main et al. (2013), cultivars with medium-sized seed produced higher yields in response to nitrogen application than did larger- and smaller-seeded cultivars. Cultivars with larger seeds had longer and stronger fibers and higher fiber length uniformity than small-seeded cultivars and decreased micronaire. Hughes et al. (2010) found that larger-seeded cultivar DP 451 had fewer neps. The smaller-seeded cultivar DP 555 BG/RR made yarn whose properties were as good as or better than that made from DP 451. DP 555 had significantly shorter length and more short fibers and neps. DP 555 produced significantly stronger and more uniform yarn than did DP 451. Edmisten (2015) reported that larger seed size and higher cool-germination values generally resulted in larger plant stands and larger plants than smaller seed size and low cool-germination values, although the effect on yield was not significant. A delicate balance is needed by the various sectors of the cotton industry to be successful. A case in point is cottonseed. Small seeds are associated with higher lint percentage but from a production standpoint, smaller seeds have lower seed vigor. Dowd et al. (2018) found that SI decreased from greater than 12 in 1964 to 9.75 in recent years, while seed-to-fiber ratio decreased from 1.7 to 1.41 (increasing lint percentage). Although vigor issues can be addressed by selecting for heavier or more dense seeds, if seed size remains small, problems will persist in post-harvest processing. For many U.S. cotton gins, seed is kept as payment, so reduced seed-to-fiber ratio decreases gin income. Small seed can pass through the gin stand with lint, which represents both a further loss of seed and an increase in seed coat fragments, causing problems in spinning. Mechanical delinting, typically performed at oil mills, is more difficult with small seeds.

The objective of this research was to investigate the effect of seed size (measured by SI) on ginning energy use, ginning rate, lint yield, fibers per seed, seed surface area, fuzz percentage, lint percentage, fiber length, strength, fiber uniformity, and fiber fineness in Upland cotton.

MATERIALS AND METHODS

Seed Characteristics and Study Site. From 2015 to 2017, nine diverse Upland cotton cultivars were planted at Stoneville, MS to study the effects of seed size (or SI) on ginning energy requirement (Wh kg^{-1} lint), ginning rate (g lint s^{-1}), lint yield (kg/ha), fibers per seed, seed surface area, fuzz percentage, gin turnout (%), number of fiber per seed, and High Volume Instrument (HVI) and AFIS quality parameters (Table 1). Two of these cultivars, AR 9317-26 and DP 555 BG/RR were classified as small seeded based on their SI weight of 100 fuzzy seeds in grams) (< 10 gm). AR 9317-26 is a semi-naked seed breeding line from the University of Arkansas. It was derived from a cross of 'H1330' with 'N-143-6' (Bourland, 1996). N-143-6 is a naked seed line developed by B.A. Waddle, a former University of Arkansas cotton breeder. Fiber Max 832 (okra) , FM 966, and MD 15 okra were classified as intermediate with SI ranging from 10 to 12 gm. MD 15 is an okra breeding line (Meredith , 2006). Entries 201-2, 107-1, and 152-1 are breeding lines at Stoneville, MS with SI > 12 gm (large). TAM 182-34 ELS (PI 654362, Smith et al., 2009) was also classified as a large-seeded cultivar (Table 1).

The experiment was conducted in a randomized complete-block design with three replications at two locations during 2015, 2016, and 2017 at Stoneville, MS. The two locations differed in soil type. One location had Bosket fine sandy loam soil that was very deep, well drained, and moderately permeable. The soil at the second location was coarse-loamy, mixed, and fine loam. Single-row, 12.2-m plots with 1.0 m between rows, were used. In all three seasons, planting was carried out during the fourth week of April at the first location but was delayed until the first week of May at the second location. Irrigation occurred three times with 76.2 mm (3 in.) of water applied each time with poly-pipe in furrows. Fertilizer application was 134 kg/ha of K_2O and 112 kg/ha of nitrogen. Prowl (Pendimethalin at 26.4 kg/ha) and Valor (Flumioxazin at 2.2 kg/ha) were pre-plant incorporated for weed control. At planting, a fungicide, Terraclor, and an insecticide, Temik, were applied at the rates of 11.2 kg/ha and 5.6 kg/ha, respectively, in the furrows. A pre-emergence herbicide, Dual Magnum^R, was applied at the rate of 0.56 kg/ha. Insecticides were also applied for thrips (Radiant at 0.11 kg/ha) and other plant bugs (e.g., Trimax™ Centric, orthene). Harvest aids used all three years were Ginstar (thidiazuron and diuron) (Bayer CropScience) and Super Boll (ethephon) (DuPont) applied at 0.63 kg/h nd 1.54 kg/ha, respectively. Fifty random bolls per sample were hand-picked from mid-September to mid-October. Lint percentage was measured from the 50 boll samples that were hand-picked from each plot. This value was used to calculate the lint yield from the mass of seed cotton spindle-picked from each plot.

Ginning Energy and Ginning Rate Measurements. Cotton was ginned using a 10-saw Continental Eagle laboratory gin (Bajaj ConEagle, LLC, Prattville, AL). All samples were ginned by the same person to reduce variability caused by different feeding techniques. Electrical power was measured with a WattsOn-1200-5A power meter (Elkor Technologies Inc., London, Ontario, Canada) with Magnelab MGC-1000-050 current transformers (Magnelab, Inc., Longmont, CO). Resolution of the power meter was 0.1 W. Data was collected at 0.01-s intervals using a Measurement Computing (Norton, MA) USB-201 data acquisition device.

Table 1. Cultivars included in the test, their seed size, seed source, and characteristics.

Cultivar	Seed Size	PI/PVP	Source	Characteristics
AR 9317-26	Small		University Of Arkansas	Semi-naked seed
DP 555BG/RR	Small	PVP 200200047	Delta and Pine Land Company	small seed, good yield
FiberMax 832	Interm.	PVP 9800258	Commonwealth Sci. and Ind. Res. Org	Nectariless, Okra leaf, Good qual.
MD 15	Interm.	PI642769	Meredith, 2006	High quality, Okra leaf
FiberMax 966	Interm.	PVP 200100209	Commonwealth Sci. and Ind. Res. Org	Many small bolls, Good yield
TAM 182-34-ELS	Large		Texas A&M University	Extra Long, staple
201-2, plant #49	Large		Breeding line from Stoneville, MS	
107-1, plant #45	Large		Breeding line from Stoneville, MS	
152-1, plant #49	Large		Breeding line from Stoneville, MS	

Ginning efficiency was described by two parameters calculated from the gin-stand power data-ginning rate and net ginning energy per unit mass. Both the rate (g s^{-1}) and energy per unit mass (Wh kg^{-1}) were calculated using the weights of seed cotton, lint, and seed. The gin-stand motor was started before cotton was fed into the stand. A 3 W increase in gin-stand power in a 0.01-s interval, along with a total increase of 30 W over the next 0.5 s indicated the start of ginning. The gin-stand motor was stopped when ginning of the sample was completed. The stop of ginning was identified by fitting a cubic polynomial to the portion of the gin-stand power data after the maximum value, and identifying when the slope of this function was less than 2W/s. The elapsed time was used to calculate the ginning rate. The total energy used by the gin-stand motor was determined by integrating the recorded power over the time that cotton was ginned. The power used by the gin stand when idling was defined as the mean value of data collected for 10 s before the start of ginning (or all data if less than 10 s from starting the motor to the start of ginning). The idling energy while ginning was equal to the idling power multiplied by the ginning time. Net ginning energy was calculated by subtracting the idling energy from the total energy. The net ginning energy reflects the energy used to remove fiber from the seed and turn the seed roll, as opposed to the energy used to overcome friction of the mechanical components of the gin stand.

Fiber Quality Measurements. HVI analysis was conducted using 20 g of lint from the 50-boll sample of each entry for fiber length, fiber strength, and micronaire at the Fiber and Biopolymer Research Institute (FBRI) of Texas Tech University in Lubbock, TX. AFIS testing was done for fineness and length by number (Lenn) using an additional 12 g of lint at the USDA-ARS Cotton Ginning Research Unit, Stoneville, MS.

SI, Fuzz Percentage, Seed Surface Area, Fibers/Seed Measurements. SI is defined as the weight of 100 fuzzy seeds in grams and is used to estimate seed size. Fuzz percentage was calculated by weighing the fuzzy seed, delinting the sample, and re-weighing the seed. The difference in weight was then divided by the weight of the fuzzy seed and multiplied by 100 to get the fuzz percentage. To calculate fibers/seed and fibers/mm^2, seeds were first scanned for total surface area with Winseedle Scanner (Groves and Bourland, 2010). The mean length by number and fineness data from AFIS data was then used with SI and lint percentage to calculate the number of fibers per seed. Dividing this result with the mean seed surface area yielded the fiber density (number of fiber/mm^2) (Bechere et al., 2009).

Statistical Analysis. All data were analyzed using the PROC GLM and PROC GLIMMIX procedures in SAS Version 9.4 (SAS Institute, Cary, NC). Means were separated using Fisher's protected LSD at the 0.05, 0.01, and 0.001 significance levels. Simple Pearson's correlation tests and regression analyses were conducted to test the relationships between SI and the traits. Covariance estimates were used to determine the direction of linear relationship between SI and the other variables.

RESULTS AND DISCUSSION

Differences among cultivars were highly significant for SI, ginning energy seed (GEseed), ginning rate seed (GRseed), lint percentage, lint yield, fuzz percentage (fuzz %), seed surface area, number of fibers/seed, number of seeds/kg, fiber length, and fiber strength (Table 2). Year effects were significant for SI, GEseed, GRseed, fuzz %, lint percentage, seed surface area, number of fiber per seed, and fiber length. High and significant location effects were observed for SI, GRseed, fuzz %, lint percentage, seed surface area, number of fibers/seed, and fiber strength. The highly significant differences between cultivars, year, location, and year*location for SI indicated that SI (used as a measure of seed size) played an important role in the above variables (Table 2).

Coefficient of determination (R^2) values were relatively high for all parameters (0.71-0.87) except for lint yield (0.47), fuzz % (0.62) and fiber strength (0.60). R^2 is a statistical measure of how close the data are to the fitted regression line. It is the percentage of the response variable variation that is explained by a linear model.

Covariance is positive when the variables show similar behavior. Cultivar*location*year covariance in Table 2 show positive values for all traits. GRseed, fuzz %, seed surface area, and fiber strength showed highly significant positive correlation with SI and had strong linear relationship with SI (Table 3, Figs. 1, 2, 3, 4). As SI increases, the seed output of the gin stand (GRseed) significantly increased. Smith et al. (1943) found that the larger and more fuzzy-seeded cottons required more time and energy to gin than the smaller and less fuzzy-seeded cultivars. GEseed, lint yield, lint percentage, number of seeds per kg, fiber length, and uniformity (Table 3, Figs. 5, 6, 7) had negative correlation and a linear, negative regression relationship with SI. The increase in SI resulted in a decrease in GEseed but an increase in GRseed (Figs. 5 and 1, respectively). Lint yield and SI had strong, negative correlation. The smaller-seeded cultivars appeared to have higher lint yield (Table 3). This result was consistent with the findings of Snider et al. (2016) who reported that seed size was negatively associated with lint yield. Campbell et al. (2011) and Kloth and Turley (2010) suggested that improvements in lint yield brought about through breeding efforts over the last several decades have been associated with an increase in lint percentage and a decline in individual seed mass. Fiber length had slight negative linear relationship with SI, but this relationship was not significant (Table 3, Fig. 7). On the other hand, fineness had a slight, nonsignificant positive correlation with seed size (Table 3, Fig. 8) .

Table 4 summarizes ginning rate and ginning energy data by SI for individual genotypes. SI mean for large-seeded entries was 12.2 g, intermediate-sized entries was 11.3 g, and smaller-seeded entries was 9.6 g. Statistically significant differences were observed for ginning rate between small-seeded cultivars and intermediate-seeded cultivars as well as between small-seeded cultivars and large-seeded cultivars. Concerning ginning rate, significant differences were observed between intermediate seed size and large-seeded groups. The effect of seed size on ginning energy requirement was more pronounced than that for ginning rate. In general, intermediate- and larger-seeded cultivars had higher ginning rate than the smaller-seeded genotypes. Concerning ginning energy, the smaller-seed group and larger-seed group required less energy to gin than the intermediate cultivars (Table 4). The higher number of seeds per pound and the higher lint percentage of the smaller seeds translated into higher lint yield for the smaller-seeded genotypes. These characteristics appear to offset the decreased seed surface area, fewer fibers in the sample, and fewer fibers/seed observed in the smaller-seeded genotypes for higher lint yield (Table 5). Small seeds were associated with higher lint percentage and higher lint yield. From production standpoint, however, small seeds have lower seed vigor and are difficult to process.

Table 2. Analysis of variance (2015–2017) for seed size, ginning efficiency, ginning rate, and other quality and agronomic parameters.

Source	DF	Seed Index[z]	GEseed[y]	GRseed[x]	Fuzz %[w]	Lint Yield	Lint Percent	Seed Surface Area[v]	No. of Seeds per lb	No. of fibers per Sd	Fiber Length	Fiber Strength
Cultivar	8	51.4***[u]	50.1***	16.24***	30.3***	12.29***	42.8***	41.0***	28.9***	39.0***	83.8***	19.1***
Year	2	48.6***	283.0***	288.5***	5.94**	0.22	33.9***	104.7***	1.44	41.5***	21.0***	2.21
Location	1	24.1***	4.2	17.92***	5.97*	3.04	32.1***	38.5***	2.34	25.7***	2.4	7.58**
Year*Loc.	2	9.8***	2.2	6.85**	10.72***	1.74	8.49***	9.70***	9.16**	2.21	0.1	18.49***
Rep	4	0.64	1.0	1.44	3.67**	0.61	0.55	2.56	1.91	3.45*	0.16	0.72
R-square		0.77	0.87	0.82	0.62	0.47	0.73	0.78	0.71	0.81	0.82	0.60
CV (%)		5.04	5.67	6.16	13.5	16.8	3.61	3.84	5.24	5.61	2.51	4.56
Mean		11.19	5.17	4.38	8.01	1182.97	37.55	109.94	1854.51	1521.39	1.18	34.2
Covariance parameter estimates												
Rep (Loc*Yr)		0	0	0.0931	3176.6	0.0664	0.6492	50.8806	815.29	0.00002	0	
Cultivar*Loc*Yr		0.2222	0.0468	1.5801	11948	0.5986	1.7845	1820.04	24646	0.0087	3.0462	
Residual		0.0693	0.0487	0.9252	30713	0.1466	8.1251	5180.13	7737.71	0.0006	1.8639	

z Seed index based on weight of 100 fuzzy seeds

y Ginning energy measured in Wh kg^{-1} lint

x Ginning Rate measured in g lint s^{-1}

w Fuzz percent was measured as (weight of delinted seed/weight of fuzzy seed) X 100

v measured by the WinSeedle Image Analysis System

u*** Significant at $p \le 0.001$; ** Significant at $p \le 0.01$; *Significant at $p \le 0.05$

Table 3. Pearson's correlation coefficients (r) of seed index, ginning energy, ginning rate and other indices.

	GEseed	GRseed	Mic.	Unif[z]	Fiber length	Fiber strength	Fine[y]	Fuzz %	Lint yield	Lint %	Seed Surface area	No. of seed/kg
Seed Index (Seed Size)	-0.3846***x (N=162)	0.5595*** (N=162)	0.1337 (N=108)	-0.2619** (N=108)	-0.1495 (N=108)	0.3488*** (N=54)	0.0385 (N=108)	0.3058*** (N=162)	-0.4914*** (N=135)	-0.6599*** (N=162)	0.8686*** (N=162)	-0.8686*** (N=108)

z Uniformity

y Fineness

x* Significant at $p \le 0.05$ level of probability; ** Significant at $p \le 0.01$ level of probability; ***Significant at $p \le 0.001$ level of probability

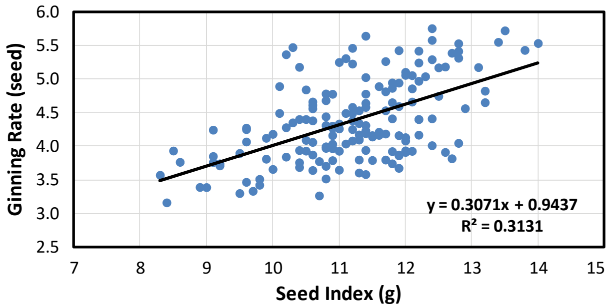

Figure 1. Effect of seed index on ginning rate on nine cultivars of Upland cotton.

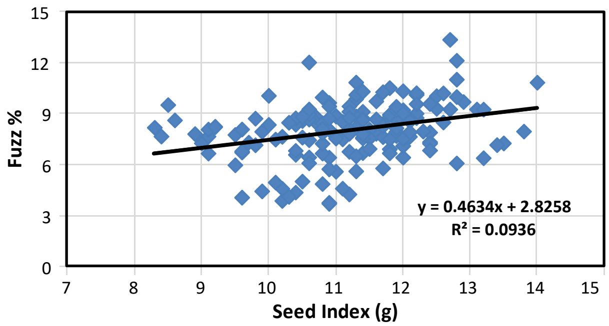

Figure 2. Effect of seed index on ginning energy on nine cultivars of Upland cotton.

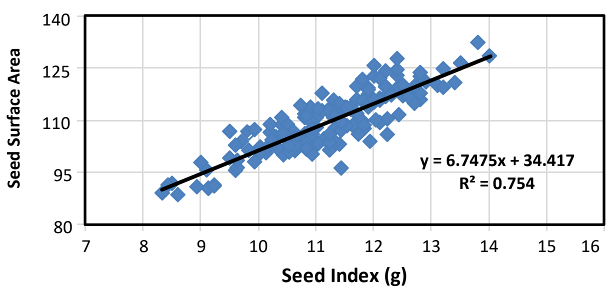

Figure 3. Effect of seed index on lint yield on nine cultivars of Upland cotton.

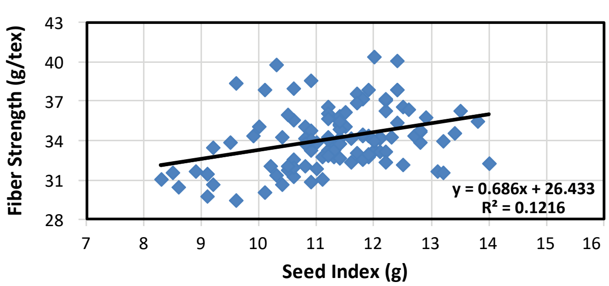

Figure 4. Effect of seed index on fuzz percent on nine cultivars of Upland cotton.

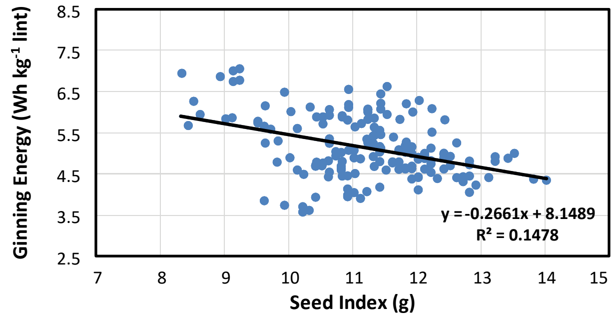

Figure 5. Effect of seed index on seed surface area on nine cultivars of Upland cotton.

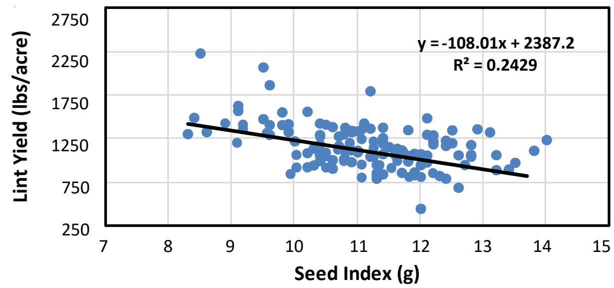

Figure 6. Effect of seed index on fiber length on nine cultivars of Upland cotton.

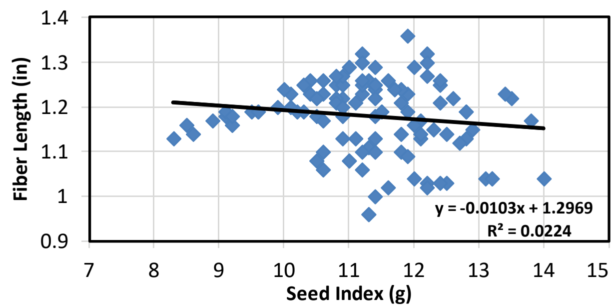

Figure 7. Effect of seed index on fiber strength on nine cultivars of Upland cotton.

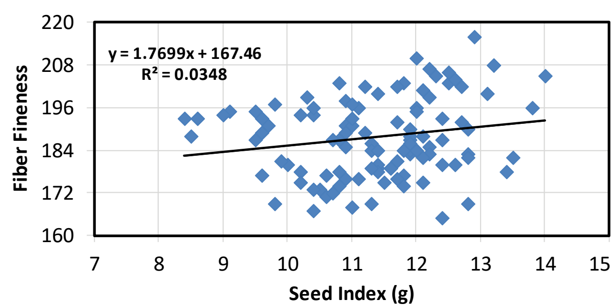

Figure 8. Effect of seed index on fiber fineness on nine cultivars of Upland cotton.

Fiber quality data on fiber length, uniformity, fiber strength, fineness, maturity ratio and Lenn are presented in Table 6. The intermediate-seeded genotypes had longer and stronger and more uniform fiber and higher L(n) (length by number) values than the smaller- and larger-seeded genotypes. On a similar line, Main et al (2013), reported that cultivars with larger seeds had longer and stronger fibers, and high fiber length uniformity than the small-seeded cultivars. Fibers from larger-seeded genotypes were finer than fibers from intermediate- and smaller-seeded genotypes (Table 6).

Table 4. Performance of individual cultivars (2015–2017) for ginning rate and ginning energy requirement based on seed index (seed size).

Cultivar	Seed Size	Seed Index[z]	Ginning Rate (g lint s^{-1})	Ginning Energy (Wh kg^{-1} lint)
AR 9317-26	Small	9.9	4.65	4.31
DP 555BG/RR	Small	9.3	3.79	6.12
Mean		9.6	4.22	5.22
FiberMax 832	Interm.	11.1	4.52	5.20
MD 15	Interm.	11.0	4.46	5.28
FiberMax 966	Interm.	11.8	4.55	5.39
Mean		11.3	4.51	5.29
TAM 182-34-ELS	Large	12.0	4.41	5.33
201-2, plant No. 49	Large	12.1	4.38	4.83
107-1, plant No. 45	Large	12.3	4.41	5.00
152-1, plant No. 49	Large	12.5	4.26	5.07
Mean		12.2	4.40	5.06
LSD (0.05)		0.37	0.18	0.19

[z] seed index (small = < 10 gm/100 fuzzy seeds, Intermediate = 10-12 gm/100 fuzzy seeds and large = > 12 gm/100 fuzzy seeds).

Table 5. Agronomic performances of individual cultivars (2015-2017) based on Seed size (seed index).

Cultivar	Seed Size[z]	Seed Index[y]	Turn Out (%)	Yield (Kg/ha)	Fuzz %[x]	Seed Surface Area[w]	Number of Seeds in a pound	Number of fibers per seed
AR 9317-26	Small	9.9	36.8	1454	5.09	107.8	4940	1231
DP 555BG/RR	Small	9.3	42.3	1796	7.58	96.8	6434	1549
Mean		9.6	39.55	1625	6.34	102.3	5687	1390
FiberMax 832	Interm.	11.1	36.5	1198	8.76	109.81	4694	1444
MD 15	Interm.	11.0	37.7	1199	7.33	109.83	4734	1515
FiberMax 966	Interm.	12.0	38.0	1165	7.81	117.34	4404	1752
Mean		11.4	37.4	1187	7.97	112.33	4611	1570
TAM 182-34-ELS	Large	12.0	37.7	1273	8.27	108.37	4062	1417
201-2, plant #49	Large	12.1	37.3	1388	8.46	113.01	4095	1560
107-1, plant #45	Large	12.3	35.2	1193	9.27	116.62	4164	1527
152-1, plant #49	Large	12.5	36.4	1259	9.52	109.94	4231	1697
Mean		12.2	36.7	1278	8.88	111.99	4138	1550
LSD (0.05)		0.37	0.89	144	0.71	2.78	78.83	69.25

z seed size = (small = < 10 gm/100 fuzzy seeds, Intermediate = 10-12 gm/100 fuzzy, seeds and large = > 12 gm/100 fuzzy seeds)

y Seed index = weight of 100 fuzzy seed

x Fuzz percent = (weight of delinted seed/weight of fuzzy seed) X 100

[w] estimated by WinSeedle Image Analysis System

Table 6. Fiber quality performance of individual cultivars (2015-2017) based on seed size (seed index)

Cultivar	Seed Size[z]	Seed Index[y]	AFIS Lenn[x]	Fine (millitex)[w]	Mic	Fiber Length (mm)	Unif (%)	Strength ($kNmkg^{-1}$)
AR 9317-26	Small	9.9	25.3	190.33	4.8	30.5	85.5	316.8
DP 555BG/RR	Small	9.3	23.9	190.92	5.0	30.1	84.1	312.1
Mean		9.6	24.6	190.63	4.9	30.3	84.8	314.5
FiberMax 832	Interm.	11.1	25.4	177.00	4.4	31.9	85.6	343.7
MD 15	Interm.	11.0	25.5	179.92	4.5	31.4	86.1	370.7
FiberMax 966	Interm.	12.0	24.3	176.75	4.6	30.7	85.0	346.1
Mean		11.4	25.1	177.89	4.5	31.3	85.6	353.5
TAM 182-34-ELS	Large	12.0	25.4	191.42	4.7	32.2	84.1	340.8
201-2, plant #49	Large	12.1	23.8	196.58	5.1	28.3	84.2	332.5
107-1, plant #45	Large	12.3	22.6	201.42	5.3	26.0	82.8	324.8
152-1, plant #49	Large	12.5	22.5	184.00	4.7	28.6	83.5	329.4
Mean		12.2	23.6	193.36	5.0	28.8	83.7	331.9
LSD (0.05)		0.37	0.86	4.91	0.16	0.02	0.86	12.39

[z] seed size = (small = < 10 gm/100 fuzzy seeds, Intermediate = 10-12 gm/100 fuzzy, seeds and large = > 12 gm/100 fuzzy seeds)

[y] Seed index = weight of 100 fuzzy seed

[x] mean length by number

[w] a relative measure of size, diameter, linear density, or weight per unit length measured in millitex

According to Boykin et al. (2012), there was a significant positive correlation between net gin-stand energy (that above idling) and fiber-seed attachment force indicating that genotypes with fibers more strongly attached to the seed required more energy to gin. There was a slight negative, but nonsignificant, correlation between ginning rate and fiber-seed attachment force. (Table 7). Boykin et al. (2012) data showed similar trends to these findings. As stipulated by Boykin et al. (2012), cultivar differences in ginning rate determined for small samples ginned on a 10-saw gin might not have been a good estimate of cultivar differences in ginning rate in a commercial gin.

Table 7. Seed size, ginning rate, ginning energy, and fiber seed attachment force for some cultivars in the study

Cultivars	Seed size	Seed Index (gm)[z]	Fiber-seed attachment force (cN*cm/mg fiber)	Ginning rate ($g\ lint\ S^{-1}$)	Ginning energy requirement ($Wh\ kg^{-1}$ lint)
AR 9317-26	Small	9.9	36.1	2.66	7.46
DP 555 BG/RR	Small	9.3	44.9	2.80	8.26
FiberMax 832 ne	Interm.	11.1	49.4	2.61	8.97
MD 15	Interm.	11.0	49.5	2.72	8.65
TAM 182 34 ELS	Large	12.0	56.8	2.68	8.74
LSD (0.05)				0.08	0.30

[z] Seed index = weight of 100 fuzzy seed (Source: Boykin et al., 2012)

CONCLUSION

Small-seeded genotypes had higher lint turnout and higher number of seeds per pound. This appears to give smaller-seeded genotypes an advantage in terms of higher lint yield. Genotypes with intermediate seed size had a lot to offer in terms of the highest ginning rate, highest AFIS Lenn, highest fiber length, strength, uniformity, seed surface area, and highest number of seeds. Large-seeded genotypes, on the other hand, had highest fineness, highest micronaire, and fuzz percentage. To corroborate these findings, a larger number of genotypes, representing the three seed-size groups, need to be included in testing. Moreover, the use of a continuous-flow gin, similar to a commercial operation, should be considered. As gin stand design has evolved, improvements have been made to remove the ginned seeds faster to increase ginning rates. Gin saw spacing also has decreased to remove lint from the seed faster, which could inhibit the removal of larger seeds. Smaller seeds should be able to exit the seed roll faster, which would increase ginning rate (and reduce ginning energy) in a continuous-flow gin. However, seeds that are too small can be removed with the lint, negatively impacting fiber quality and spinning performance. In the batch-process 10-saw gin, seeds remain in the seed roll until the gin is stopped, so seed removal has no effect on ginning rate.

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DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S Department of Agriculture.

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