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BREEDING, GENETICS, & GENOMICS

Yield Component Score, a Method for Characterizing Cotton Lines Relative to Primary Yield Components

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ABSTRACT

Increased lint yield of cotton (*Gossypium hirsutum* L.) cultivars is the primary objective of most cotton breeding programs. Partitioning lint yield into yield components can provide the opportunity to improve lint yield by indirect selection. Lint yield can be defined as the product of lint index (LI) and number of seed per area (SPA). A subjective yield-component rating (YC1) of relative ranks of LI and SPA in University of Arkansas (UA) strain tests has been used to identify lines that have favorable relationships of LI and SPA. An objective, computer-generated application, yield component score (YC-score), is available to identify these lines. We were able to generate four years of YC-scores for the 67 UA lines released since 2007. High correlations between YC-score and YC1 indicated that YC-score captured the intent of the YC1 ratings. YC-scores of the 67 released lines were relatively consistent over years of testing and varied greatly among the lines. YC-score was calculated for entries in eight Regional Breeders' Testing Network (RBTN) tests and correlated with lint yield and other yield component variables. YC-score varied among entries in each RBTN test. Correlations with YC-score were highest for LI, SPA, fibers per seed, S-score, and seed index. Negative correlations between YC-score and lint yield in all eight RBTN tests indicate that it should not be used as a primary selection tool. Among high performing cultivars, YC-score can differentiate those that have the most favorable yield component values.

The development of lines that produce stable and high yields is a primary objective of most, if not all, cotton breeding programs. Most increases in lint yields of cotton cultivars have been realized by increasing the volume and/or precision of selection of lines and by enhanced testing of derived lines. However, expression of lint yield is greatly affected by interactions with the environment, which decreases the response of lint yield to direct selection. Enhanced use of yield components provides the opportunity to make indirect selection for increase yield and stability.

Various component models for lint yield have been proposed. Yield component models often define lint yield as the product of various parameters such as number of plants per area, number of bolls per plant, seed cotton per boll and lint percent. Lewis et al. (2000) proposed lint yield in cotton could be modelled as the number of seed per area (SPA) times the weight of lint per seed. Weight of lint per seed is often expressed as lint index (LI), which is the lint weight per 100 seed. This two-component model assumes that plant density within an acceptable range does not greatly influence lint yield. Bednarz et al. (2000) cited several studies of plant population densities that confirm this assumption in cotton.

Based on this model, lint yield can be increased by increasing either LI or SPA (Lewis et al., 2000). At least four factors contribute to the efficiency and logic of increasing cotton yield by prioritizing LI over SPA. First, seed cotton, which normally expresses approximately 40% lint contains approximately 1.5 times more seed weight than lint weight. Thus, from a gravimetric perspective, lint weight must be increased proportionately less than seed weight to increase lint yield. Secondly, cottonseeds contain approximately 1.5 times as much carbon compared to cotton lint. Consequently, a great deal more carbon must be fixed to achieve lint yield by increasing SPA than by increasing LI. Thirdly, from an energy equivalency basis, cottonseeds contain approximately 20% triglycerides (or oil). Approximately 2.24 times more energy is required to produce a unit of triglyceride than it does to produce the same amount of cellulose. Because more plant energy is required to produce equal weights of seeds than fiber,

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yield stability should be improved by selecting lines that produce lint yields based on relative preference of LI over SPA. Finally, from an inheritance basis, heritability of LI is much greater than the heritability of SPA and thus is more responsive to selection.

Cotton breeding programs generally do not focus selection for LI and SPA as yield components. Perhaps the main reason for little attention placed on LI and SPA is the time and labor associated with determining seed index (weight of 100 seed, SI). Measurement of SI is required to calculate both SPA and LI, as well as other yield component variables, for example, fibers per seed, seed surface area, and fiber density (Groves et al., 2016).

LI is a function of seed surface area and selection for increased LI results in larger seeds. Large seed size is unfavorable due to its association with lower lint percentages and thinner seed coats. Bechere et al. (2021) indicated as seed size increased, ginning rate increased but ginning energy requirement decreased. However, both germination and seed vigor increase as SI increases (Krieg and Carroll, 1978; Kunze et al., 1969; Minton and Supak, 1980; Snider et al., 2014). Conversely, smaller seeds are related to higher lint percentages, but their smaller cotyledons are often associated with decreased stand and lower seedling vigor (Snider et al., 2016).

SPA has a greater influence on lint yield than does LI. Groves et al. (2016) evaluated data from six categories of cotton tests conducted at multiple sites in Arkansas over eight years. They found that the direct influence of SPA on lint yield averaged 87.0% over the six categories of tests with the greatest influence observed in non-irrigated tests. In comparison, the direct influence of LI on lint yield averaged 30.8% in the same tests. They also found that SPA and LI expressed location × entry interactions in 70% and 30% of the tests, respectively. These data demonstrate SPA is greatly influenced by environmental conditions and varies greatly by multiple growth and development factors with many interactions. Consequently, SPA expresses a low heritability and does not respond well to selection. Using 19 years of data obtained from the Arkansas Cotton Variety Testing Program, Virk et al. (2023) found that a regression function using LI and SPA was a stronger and more consistent indicator of genotypic variation in lint yield than any yield component.

Obviously, lint yield cannot be produced without both seed and lint production. Lint yield of a cotton line that relies greatly on SPA to produce lint yield can suffer low yield stability. In contrast, heavy reliance on LI can reduce yield potential. Identical lint yields can be achieved by cultivars having different combinations of LI and SPA. However, cultivars that derive lint yield using relatively high lint index should produce more stable and efficient lint yields. Yield component score (YC-score) attempts to provide a direct measure of the proportional influence of LI and SPA to lint yield. YC-score can be used in conjunction with two previously developed scores: quality-score (Q-score) and seed-score (S-score). Q-score was developed to provide an index of primary fiber quality parameters and is used to identify lines having high fiber quality (Bourland et al., 2010). S-score attempts to normalize seed index and lint index into a single index with penalties for both high and low seed index values and no penalty for high lint index values (Bourland et al., 2022).

MATERIALS AND METHODS

LI and SPA Calculation. LI can be calculated using lint and seed weight data, which are normally produced from ginning small samples plus the determination of SI from the seed samples. SI can be determined by counting either delinted seed or fuzzy seed. Fuzzy seed are difficult to count because they cannot be metered through standard seed counters. Although they require more time to count than delinted seed, fuzzy seed do not require the labor and time associated with delinting. Also, because seed percentage parameter used in the calculation of SPA (see below) is based on weight of fuzzy seed from the gin, fuzzy SI should provide a more accurate estimation of number of seed per sample than does delinted SI. If weight loss during ginning is minimum, seed percentage should be a near reciprocal of lint percentage.

We began routinely measuring SI in the Arkansas Cotton Variety Testing in 1999 and in the University of Arkansas (UA) Cotton Breeding Programs in 2003. Currently, we measure SI by counting and weighing two sets of 25 fuzzy (gin-run) seed from each ginned sample. If the difference of the two seed weights is ≥ 0.2 g, two additional 25 seed sets are counted and weighed. SI is then calculated by doubling the sum of the middle two weights. Typically, fewer than 5% of our samples meet or exceed the 0.2-g tolerance limit. SI is then expressed as the weight of 100 fuzzy seed. After SI is determined, LI and SPA are calculated using weights of lint and seed from a ginned sample and seed cotton yield as:

LI = (weight of ginned lint, g / number of seed per sample) *100, where

No. of seed per sample = weight, g of fuzzy seed / (fuzzy SI / 100).

Seed per area (SPA) can be calculated as number per acre or number per hectare:

SPA (acre) = ((seedcotton yield (lb/a) * seed %) * 454) / (SI/100), or

SPA (hectare) = ((seedcotton yield (kg/ha) * seed %) * 1000) / (SI/100).

Logic and Calculation of YC-Score. The logic and calculation of YC-score differs from the patterns used for Q-score and S-score. Calculation of Q-score was quantitatively based on variation in fiber parameters obtained from USDA Classing Office data for the 2001 through 2005 U.S. cotton crops (Bourland et al., 2010). Mean and standard deviation for standard High-volume instrument (HVI) fiber parameters were determined for the millions of bales in this data set.

Means and standard deviations for SI and LI needed for the calculation of S-score were not readily available from USDA or other cotton testing programs. The data set used for establishing S-score was extracted from 21 years (1999 through 2020) of the Arkansas Cotton Variety Testing program, which produced a total of 6453 lines of data for SI and LI (Bourland et al., 2022). Each line of data for SI and LI was the average of two replications, which represented the field plots from which boll samples were collected. These data produced mean SI of 10.17 ± 1.07 g and mean LI of 7.01 ± 0.90 g. Although not used in S-score, this data set produced mean SPA of 7.006 ± 1.954 ml seed with each line of data representing the average of four replications. The relatively high standard deviation associated with SPA reflects the relatively high degree of environmental influence on the parameter. Although both SPA and LI were available in this large data set, a YC-score based on means and standard deviations of SPA would likely have little value. Because lint yield is highly defined by SPA (Groves et al., 2016), entries in low yielding tests would have a low YC-score even though they might exhibit an excellent LI to SPA relationship.

Determination of YC1. Beginning in 2013, a subjective yield component rating (YC1) was assigned to each entry in six replicated strain tests conducted each year within the UA Cotton Breeding Program. Each of the tests had an equal number of entries and included 18 UA strains and two check cultivars. YC1 was our initial attempt to indicate how efficiently breeding lines obtained their lint yields and was used as a factor in advancing lines. YC1 was based on the relative ranks of SPA and LI means over locations of the tests and was assigned values using a scale of: 1 = relatively high LI but relatively low SPA, 2 = moderately high LI but moderately low SPA, 3 = near equal and moderate LI and SPA, 4 = moderately low LI but moderately high SPA, and 5 = relatively low LI but relatively high SPA. Because low SI would likely produce higher SPA and lower LI, the relative influence of SPA was subjectively diminished on strains that had low SI. Having an equal number of entries in each test provided the same range of ranks and helped to increase consistency of YC1 ratings.

YC1 ratings in UA strain tests were based on means over replications and over locations. Because we typically had SPA data from four replications but had LI data for only two replications of the tests, using means over replications avoided unbalanced sets of data. YC1 based on means over locations should provide values that reflect performance over multiple environments and ignore possible genotype × environment effects on the parameter.

YC-Score Calculation. To determine if the subjective YC1 rating could be calculated from SPA and LI values, a calibration data set was used from the 2022 UA Advanced Strain test, which included 20 entries (10 F6, 8 F7 strains, and 2 check cultivars) evaluated over four locations in Arkansas. Bourland (2004, 2013) described the development and evaluation of advanced strains in the UA Cotton Breeding Program. As YC1 was based on relative ratings within a given trial, the first step was to normalize the SPA and LI data so that the score would be consistent across locations and years. The normalization bounds were defined using the mean and standard deviation of the values observed in the trial: the minimum value was set as the mean minus two standard deviations (L), and the maximum as the mean plus two standard deviations (U). Any input value below the minimum threshold was set to 0, and any value above the maximum was set to 1. For the remaining values, a linear transformation was applied so that the normalized value increased proportionally from 0 to 1 using the formula:

$$N = \frac{(X-L)}{(U-L)},$$

where N is the normalized value and X is the observed value of either SPA or LI.

Next, a linear regression was conducted with YC1 as the dependent variable, and the normalized values of SPA and LI as the dependent variables. YC1 was treated as a continuous variable in the regression analysis; therefore, the regression output, YC1r, was not constrained to whole numbers. Thus, YC1r could have values less than 1 and greater than 5, so that it was necessary to normalize YC1r using the prior equation for N, where L and U were the minimum and maximum values of the regression equation, respectively. Then YC-score was calculated as:

$$\text{YC-score} = 100\ (1 - YC_{rn}),$$

where YCrn is the normalized regression output for YC1. The YC-score is comparable to Q-score and S-score in that 100 represents the most desirable condition, and 0 the least desirable. The described YC-score calculations were performed in an Excel spreadsheet and macro (Microsoft 365, version 2011). The spreadsheet can be obtained through a request to the third author (DJones@cottoninc.com).

YC-Scores of UA Released Lines. Since 2003, LI and SPA data have been collected in all UA strain tests and were used to retrospectively calculate YC-scores. In the UA Advanced Strain Tests conducted in 2019 through 2024, YC-score for each strain was calculated using mean LI and SPA over locations (YCS-over) and was also calculated using mean LI and SPA within each location then averaged over locations (YCS-avg). In those five years, Pearson's correlations of YCS-over with YCS-avg ranged from 0.976 to 0.997. Based on these results, YC-scores in all UA strain tests conducted since 2003 were calculated using means LI and SPA over locations within a year, that is, YCS-over.

The UA Cotton Breeding Program has released 67 lines since 2007 (Table 1). Typically, lines released from the UA Cotton Breeding Program are evaluated in strains tests at four Arkansas test sites for four years (Bourland, 2004, 2013). LI and SPA data for the lines released in 2007 were first collected in 2003. Each test included 18 UA strains and two check cultivars (Table 1). Therefore, four annual estimates of YC-score were made for each released strain.

YC-Score in the Regional Breeders' Network Test (RBTN). The RBTN test is annually conducted over multiple locations (including Keiser, AR) to evaluate advanced conventional cotton lines developed primarily by public breeders (http://rbtn.cottoninc.com/files/). Because boll samples are taken from each of four replications of RBTN, LI and SPA data were available to establish a YC-score data set that could be subjected to ANOVA within each year. YC-scores were calculated for all entries in 2017 through 2024 RBTN tests at the Keiser, AR, location of the RBTN. These years were selected because they included four common check cultivars: DP 393 (PVP 200400266), DP 493 (PVP 200300312), FM 958 (PVP 200100208), and UA222 (U.S. patent no. 8,859,862; Bourland and Jones, 2012b).

In addition to SI, LI, and SPA, the RBTN data included measurements of lint yield, lint percentage, S-score, number of fibers per seed (FPS), and Q-score. FPS was estimated by dividing the average weight of lint per seed by the average weight per fiber using the equation from Lewis et al. (2000):

$$\text{fibers seed}^{-1} = \frac{\text{lint index}/100}{\text{UHM}\times(\text{UI}/100)} \times \frac{\text{micronaire}}{1{,}000{,}000},$$

where UHM is the upper-half mean fiber length and UI is the length uniformity index.

HVI fiber parameters on all samples were determined by the Louisiana State University AgCenter Cotton Fiber Laboratory (Baton Rouge, LA). Q-score, an index of four fiber quality parameters, was calculated using the methods and macro described by Bourland et al. (2010). The relative weight assigned to the fiber quality parameters to calculate Q-score in these tests were length (50%), micronaire (25%), length uniformity (15%), and strength (10%).

Within each year, Pearson's correlations of YC-score with LI, SPA, SI, lint yield, lint percentage, FPS, S-score, and Q-score were determined based on individual plot data. The number of observations in each correlation coefficient was equal to the number of entries times four (the number of replications). For analysis of YC-score over years, data for the four check cultivars were extracted from the 2017 to 2024 RBTN tests and evaluated by ANOVA. All data were analyzed by SAS v. 9.4 PROC GLM (Release 9.4, SAS Institute, Cary, NC). For data collected over years, years and replications were considered to be random, whereas entries were fixed.

Table 1. Subjective YC1 ratings (after 2012) and calculated YC-scores (YCS) over four years of replicated tests in Arkansas for 67 cotton lines released since 2007.

		Year 1		Year 2		Year 3		Year 4		Mean over yrs		
Line	1st Year	YC1	YCS	YC1	YCS	YC1	YCS	YC1	YCS	YCS	Rank	Release citation
Arkot 9608ne	2003		19		20		14		7	15 ± 6	66	Bourland & Jones, 2008a
Arkot 9610	2003		45		76		55		27	51 ± 20	35	Bourland & Jones, 2008b
Arkot 9620	2003		62		78		55		32	57 ± 19	28	Bourland & Jones, 2008b
Arkot 9623	2003		28		35		20		43	32 ± 10	61	Bourland & Jones, 2009a
Arkot 9625	2003		86		90		81		39	74 ± 24	11	Bourland & Jones, 2009a
Arkot 9704	2004		58		73		59		86	69 ± 13	15	Bourland & Jones, 2009b
Arkot 9706	2004		73		73		80		72	75 ± 4	9	Bourland & Jones, 2009b
Arkot 9721	2004		20		42		58		20	35 ± 19	58	Bourland & Jones, 2009c
Arkot 9811	2005		56		37		20		27	35 ± 16	59	Bourland & Jones, 2010
Arkot 9815	2005		68		53		28		44	48 ± 17	42	Bourland & Jones, 2010
'UA103'	2005		75		84		84		62	76 ± 10	7	Bourland & Jones, 2013
Arkot 0008	2006		15		6		0		6	7 ± 6	67	Bourland & Jones, 2011a
Arkot 0009	2006		62		70		25		38	49 ± 21	39	Bourland & Jones, 2011a
Arkot 0012	2006		79		68		71		39	64 ± 17	19	Bourland & Jones, 2011a
Arkot 0015a	2006		72		65		56		48	60 ± 10	24	Bourland & Jones, 2011b
Arkot 0015b	2006		81		57		91		55	71 ± 18	14	Bourland & Jones, 2011b
Arkot 0016	2006		89		87		76		68	80 ± 10	5	Bourland & Jones, 2011b
'UA48'	2007		70		34		58		41	51 ± 16	36	Bourland & Jones, 2012a
Arkot 0111	2007		62		59		70		46	59 ± 10	25	Bourland & Jones, 2014a
Arkot 0113	2007		50		34		40		25	37 ± 11	54	Bourland & Jones, 2014a
Arkot 0114	2007		77		74		79		77	77 ± 2	6	Bourland & Jones, 2014a
'UA222'	2008		55		40		40		35	43 ± 9	52	Bourland & Jones, 2012b
Arkot 0219	2008		64		65		79		90	75 ± 12	10	Bourland & Jones, 2014b
Arkot 0222	2008		54		39		50		74	54 ± 15	32	Bourland & Jones, 2014b
Arkot 0305	2009		41		46		32		28	37 ± 8	56	Bourland & Jones, 2015a
Arkot 0306	2009		22		23		7		23	19 ± 8	65	Bourland & Jones, 2015a
Arkot 0309	2009		35		63		36		55	47 ± 14	47	Bourland & Jones, 2015a
Arkot 0316	2009		35		28		57		72	48 ± 20	43	Bourland & Jones, 2015a
Arkot 0403ne	2010		64		42		46	4	40	48 ± 11	44	Bourland & Jones, 2015b
Arkot 0409	2010		47		58		58	4	54	54 ± 5	33	Bourland & Jones, 2015b
Arkot 0410HG	2010		78		92		99	1	82	88 ± 10	1	Bourland & Jones, 2015b
Arkot 0502ne	2011		73		57	3	51	5	53	59 ± 10	26	Bourland & Jones, 2017
Arkot 0504ne	2011		64		48	4	31	4	36	45 ± 15	48	Bourland & Jones, 2017
Arkot 0506ne	2011		47		36	4	43	4	40	42 ± 5	53	Bourland & Jones, 2017
Arkot 0517HG	2011		85		84	1	80	1	100	87 ± 9	2	Bourland & Jones, 2017
Arkot 0611	2012		50		38	4	56	2	83	57 ± 19	29	Bourland et al., 2019
Arkot 0617	2012		55		45	3	48	3	55	51 ± 5	37	Bourland et al., 2019
'UA114'	2012		36		25	4	28	5	23	28 ± 6	62	Bourland & Jones, 2018a
Arkot 0705	2013	2	59	3	59	4	32	2	73	56 ± 17	30	Bourland & Jones, 2018b
Arkot 0711	2013	2	76	3	52	1	80	3	55	66 ± 14	17	Bourland & Jones, 2018b
Arkot 0712	2013	5	79	5	47	5	49	5	17	48 ± 25	45	Bourland et al., 2019
'UA107'	2013	1	83	1	73	1	64	1	80	75 ± 8	8	Bourland & Jones, 2018c
'UA212ne'	2014	5	22	3	53	1	74	3	47	49 ± 21	38	Bourland & Jones, 2020

Table 1. continued

		Year 1		Year 2		Year 3		Year 4		Mean over yrs		
Line	1st Year	YC1	YCS	YC1	YCS	YC1	YCS	YC1	YCS	YCS	Rank	Release citation
'UA248'	2014	5	35	3	47	3	62	3	64	52 ± 14	34	Bourland & Jones, 2021a
Arkot 0822	2014	3	69	1	70	2	68	1	49	64 ± 10	20	Bourland & Jones, 2021b
Arkot 0902	2015	3	41	4	40	4	27	4	41	37 ± 7	55	Bourland et al., 2023
Arkot 0908-52	2015	2	52	1	74	4	50	3	53	57 ± 11	27	Bourland et al., 2021
Arkot 0908-56	2015	1	76	1	77	1	69	2	53	69 ± 11	16	Bourland et al., 2021
Arkot 0908-60	2015	2	54	4	43	3	52	4	43	48 ± 6	46	Bourland et al., 2021
Arkot 0912-18	2015	2	58	2	62	1	69	1	72	65 ± 6	18	Bourland & Jones, 2022
Arkot 0912-41	2015	1	87	1	81	1	89	1	79	84 ± 5	3	Bourland & Jones, 2022
Arkot 1005	2016	1	61	2	82	1	87	1	65	74 ± 13	12	Bourland & Jones, 2023a
Arkot 1015	2016	3	50	4	52	4	38	4	37	44 ± 8	49	Bourland & Jones, 2023a
Arkot 1019	2016	2	26	4	20	4	29	5	14	22 ± 7	64	Bourland & Jones, 2023a
Arkot 1102ne	2017	3	47	5	30	4	43	3	53	43 ± 10	51	Bourland & Jones, 2024
Arkot 1112	2017	1	68	1	54	3	57	3	66	61 ± 7	23	Bourland & Jones, 2023b
Arkot 1114	2017	4	35	4	37	4	36	4	36	36 ± 1	57	Bourland & Jones, 2023b
Arkot 1115	2017	1	62	3	51	1	64	3	41	55 ± 11	31	Bourland & Jones, 2023b
Arkot 1202	2018	2	63	1	65	1	82	4	46	64 ± 15	21	Bourland et al., 2024
Arkot 1207	2018	3	42	4	35	4	29	3	22	32 ± 9	60	Bourland et al., 2024
Arkot 1208	2018	1	68	1	56	1	71	1	55	63 ± 8	22	Bourland et al., 2024
Arkot 1214	2018	4	40	4	35	4	49	2	53	44 ± 8	50	Bourland et al., 2024
Arkot 1301	2019	1	62	1	93	1	91	1	90	84 ± 15	4	Bourland & Jones, 2025
Arkot 1308	2019	2	47	3	47	4	35	2	66	49 ± 13	40	Bourland & Jones, 2025
Arkot 1309	2019	1	66	2	74	1	78	1	73	73 ± 5	13	Bourland & Jones, 2025
Arkot 1311	2019	3	51	3	47	4	56	3	41	49 ± 6	41	Bourland & Jones, 2025
Arkot 1317	2019	5	24	5	21	5	26	3	41	28 ± 9	63	Bourland & Jones, 2025
Mean		2.5	56.0	2.4	54.0	2.5	54.0	2.8	50.3	53.6		
Correl. YC1 vs YCS		-0.623		-0.837		-0.882		-0.789				

RESULTS AND DISCUSSION

Relation of YC1 and YC-Score. Table 2 provides the results of the regression analysis between YC1 and the normalized values of SPA and LI. Both terms were significant in predicting YC1, and based on the magnitude of the regression coefficients, YC1r is more responsive to changes in the normalized values of LI than SPA. Given the linear regression relationship explained 87% of the variation in YC1 for the calibration data set (Fig. 1), more complicated relationships were not evaluated.

YC1 and YC-score were highly correlated in each year of development of the 67 released UA lines (Table 1). Low (favorable) YC1 ratings were associated with high YC-scores in each generation of testing. Lines were evaluated in one of four Preliminary Strain Tests in Year 1, in the New Strain Test in Year 2, and Advanced Strain Tests in Years 3 and 4. The lowest correlation coefficient between YC1 and

Table 2. Parameter estimates of YC1r predicted using a linear regression model with normalized values of LI and SPA.

	Coefficients	Standard Error	t Stat	*p*-value
I	3.78	0.37	10.2	1.17E-08
C_{LIn}	-3.78	0.46	-8.2	2.55E-07
C_{SPAn}	2.09	0.44	4.77	0.000179

I = intercept, C_{LIn} and C_{SPAn} = the regression coefficients for the normalized values of LI and SPA respectively.

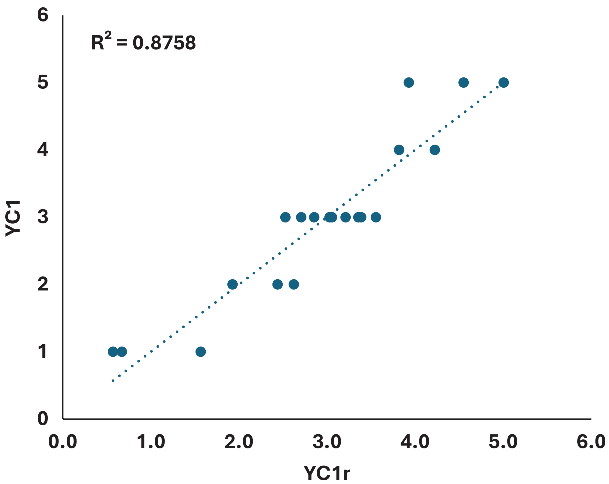

Figure 1. The subjective YC1 value versus the regression estimate based on SPA and LI data (YC1r) for the 2022 University of Arkansas Advanced Strain Test.

YC-score occurred in the Preliminary Strain Tests. The high correlations indicate that the calculated YC-score captured the intent of the subjective YC1 ratings.

Variation in YC-Scores among UA Released Lines. YC-scores for the 67 UA strains were relatively consistent over years of testing (Table 1). Standard deviation associated with YC-score of 31 lines was less than 10. Most of the 15 lines having a standard deviation exceeding 15 had one outlying year, which might have been associated with experimental error. Mean YC-score varied from 88 for Arkot 0410HG to 7 for Arkot 0008. The top 10 lines had YC-scores equal to or greater than 75 and included the only two high glanding lines (Arkot 0410HG and Arkot 0517HG) and the only two okra leaf lines (UA103 and UA107) among the released lines. The seven nectariless released lines expressed average YC-score = 43 with an average rank of 47. Because the lines do not include isolines, these associations do not verify associations of YC-score with morphological traits. Ten of the 67 lines had YC-score of less than 35 and included five derived from crosses made before the year 2001. However, YC-score did not appear to be strongly related to year of release. Three lines (Arkot 0114, Arkot 9706, and Arkot 0912-41) were among the highest 10 YC-scores and lowest 10 standard deviations.

Five conventional cultivars have been progressively used as the two checks in the UA strain tests with PSC 355 and SG 105 (PVP 009900190) in 2003-2004, SG 105 and DP 393 in 2005-2009, DP 393 and UA48 in 2010-2014, and UA48 and UA222 in 2015-2023 (Table 3). Average YC-score for UA48 was equal to UA222 and both were higher than YC-scores for PSC 355, SG 105, and DP 393. The higher values for UA48 and UA222 might reflect attention to LI and SPA during the development of these lines. Mean YC-scores for the check cultivars were intermediate to the values for the released strains (Table 1).

Variation in YC-Scores in RBTN Tests. Variation among entries for YC-score was found in each year of the RBTN test (Table 4). The high R2 values indicate that most variation in YC-score was principally due to entries and replications. The YC-scores of the four check cultivars were relatively consistent each year. Over the eight years, UA222 had a higher YC-score than the other three cultivars and was comparable to the overall mean of released strains (Table 1). The difference between UA222 and DP 393 in the RBTN tests was comparable to that found in the UA strain tests (Table 3).

LI and SPA were highly correlated with YC-score in each year of the RBTN tests (Table 5). YC-score is structured to identify lines that rely more heavily on LI than on SPA to produce lint yield. Thus, LI and SPA were, as expected, positively and negatively related to YC-score, respectively. In each year, YC-score was more closely related to LI than SPA. YC-score was also correlated with S-score and FPS in each year, which might be expected because

Table 3. Variation in YC-scores for check cultivars in Arkansas strain tests.

Cultivar[z]	Years	No. of tests	YC-score
PSC 355	2003 – 2004	8	40.6 ± 13.3
SG 105	2003 – 2009	28	39.7 ± 13.5
DP 393	2005 – 2014	40	44.4 ± 11.1
UA48	2010 – 2023	56	59.6 ± 12.3
UA222	2015 – 2023	36	58.3 ± 11.5

[z]Two conventional cultivars were used as checks in each test. Checks cultivars were changed as older cultivars became obsolete.

Table 4. YC-scores for four check cultivars and summary statistics associated with the Regional Breeders' Testing Network (RBTN) test conducted at Keiser, AR, in 2017 through 2024.

	YC-score by year[z]								
Check	2017	2018	2019	2020	2021	2022	2023	2024	YC-score over years[y]
DP 393	51	54	37	57	36	61	48	62	51
DP 493	39	24	37	26	45	46	15	40	39
FM 958	61	46	52	63	39	44	26	53	52
UA222	74	67	53	62	37	79	67	74	65
No. entries	34	24	24	16	28	32	24	27	4
Mean	49	49	49	48	49	48	49	49	51
LSD 0.10	10	14	15	17	16	15	14	14	3
C.V. (%)	19.7	27.0	26.1	28.7	28.6	25.6	23.8	24.1	24.3
R2 * 100	71.9	69.3	63.6	63.7	63.1	66.6	71.5	71.3	69.7

[z]YC-score analysis by year included all entries in each test.

[y]YC-score analysis over years included only the four check cultivars.

Table 5. Simple correlation coefficients of YC-score with lint index (LI), seed per area (SPA), fibers per seed (FPS), seed-score (S-score), seed index (SI), lint yield, lint percent, and quality score (Q-score) in the Regional Breeders' Testing Network (RBTN) tests conducted at Keiser, AR, in 2017 through 2024.

	Simple correlation coefficients by year							
Variable	2017	2018	2019	2020	2021	2022	2023	2024
LI	0.831	0.885	0.853	0.890	0.893	0.857	0.867	0.855
SPA	-0.287	-0.670	-0.410	-0.554	-0.624	-0.462	-0.485	-0.461
FPS	0.655	0.476	0.393	0.497	0.561	0.604	0.743	0.571
S-score	0.406	0.463	0.434	0.649	0.552	0.421	0.699	0.393
SI	0.432	0.474	0.534	0.238	0.439	0.438	0.363	0.622
Lint yield	-0.094	-0.451	-0.164	-0.331	-0.345	-0.111	-0.356	-0.230
Lint percent	0.325	0.175	0.131	0.152	0.474	0.236	0.369	0.042
Q-score	0.087	0.236	0.236	0.350	0.189	-0.013	-0.176	0.143
Observations	136	144	144	64	112	128	144	108
Critical r value[z]	0.222	0.216	0.216	0.325	0.245	0.227	0.216	0.249

[z]Within years, correlation coefficients greater than the critical value differ from zero at p = 0.01 level.

LI is directly associated with calculation of both S-score and FPS. In addition, YC-score was correlated with SI in seven of the eight years. To some extent, SI and LI are related with larger seed having higher LI.

Relationships of YC-score with lint yield, lint percentage and Q-score were relatively weak and not consistent over years (Table 5). Lint yield was negatively related to YC-score in all years, but correlation coefficients differed from zero in only four of the eight years. Because lint yield is the product of LI and SPA, the negative relationship between lint yield and YC-score is not surprising because SPA was negatively related to YC-score. Also, Groves et al. (2016) found that SPA averaged 2.7 times greater direct on lint yield than did LI. Therefore, the negative relationship of SPA on YC-score appeared to overwhelm the positive effect of LI on YC-score.

Lint percentage was positively associated with YC-score but correlation coefficients differed from zero in only four of the eight years (Table 5). Finally, Q-score was weakly related to YC-score with positive correlation coefficients in only three of the eight years. Based on these corrections, direct selection for high YC-score will not likely affect lint percentage or fiber properties.

SUMMARY

Cotton yield can be defined as the product of two components, LI and SPA. Lint production requires less plant energy than seed production. Thus, cotton lines that rely more heavily on LI should be favored over ones that depend heavily on SPA to produce lint yield. In 2010, we began using YC1 of relative ranks of LI and SPA within strain tests to identify lines that possessed the most favorable combination of these two yield components. YC-score is a computer-based application that was developed to provide an objective measure of the relative relationship of the two yield components.

Because LI and SPA were measured in all UA strain tests since 2003, we were able to generate four years of YC-scores for the 67 UA lines released since 2007. Strong correlations between YC-score and YC1 indicated that YC-score captured the intent of the YC1 ratings. YC-scores of the 67 released lines were relatively consistent over years of testing and varied greatly among the lines. UA48 and UA222 consistently produced higher YC-scores than check cultivars developed by other programs.

YC-scores were calculated in four replications of lines in 2017-2024 RBTN tests at Keiser, AR. Within each year, relatively high amount of test variability was explained by entries and replications and YC-score varied significantly among entries. Correlations with YC-score were highest for LI, SPA, FPS, S-score, and SI. LI and SPA were directly associated with the calculation of YC-score, whereas FPS and S-score were calculated using LI, and SI is related to LI. YC-score being negatively related to lint yield in all eight RBTN tests indicates that it should not be used as a primary selection tool. Instead, YC-score might be used to distinguish which high yielding lines are developing lint yield in the most efficient manner. An optimum relationship of SPA and LI to produce high lint yields should exist and will be addressed in the future.

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