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Evaluation of Segregating Generations of Upland Cotton (*Gossypium hirustum* L.)

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ABSTRACT

The present study contained 16 testing genotypes and was laid out in a Randomized Complete Block Design (RCBD) with four replications at Werer Agricultural Research Center (WARC). This experiment was conducted with the objective of evaluating the performance of segregating inbred lines. The analysis of variance revealed that the tested genotypes differed significantly (p<0.05) in number of sympodial branches plant-1(SYM), Plant height (PLH), boll number plant-1 (BOP), Boll weight (BOW), Seed cotton yield ha-1 (SHA),Ginning percentage (GP),and lint yield ha-1(LHA), hundred seed weight (HSW), micronaire (Mic), upper half mean length (Uhml), Fiber Strength(Str) and Short fiber content (Sf). A one degree of contrast between the mean of the 14 F5 inbred lines and the mean of the two parents was significant for all traits except some traits. All 14 inbred lines included in this study were better than both parents in SYM, BOP, SHA, GP, and LHA, but were inferior to both parents in BOW, indicating that there was transgressive expression of the majority of traits. Additive genes were dispersed in the two parents for these traits. The mean separation analysis of seed cotton yield revealed superior inbred lines that excelled their parents viz., K (5170.3kg/ha), G (5072 kg/ha) and I (4987 kg/ha). The yield advantage obtained from most of the inbred lines was more than 10% in both seed cotton yield and lint yield compared with the parents. The inbred line with the highest value was superior to the parent with the highest value by 34% in SYM (inbred line I (15.25 vs 11.38), by 39.94% in BOP (inbred line I; 17.59 vs 12.57), by 26.7% in SHA (inbred line K; 51.7 vs 40.8), by 33.1% in LHA (inbred line K; 20.92 vs 15.72). Deltapine-90 was inferior to Delecero in Upper half mean length (Uhml) (27.90 vs 32.92), Uniformity percentage (80.4 vs 83.88), and in Strength (25.78 vs 36.33). The higher fiber quality of Delecero was expressed in its higher Uhml, strength, and its lower percentage of short fiber content (Sf, 8.0%).Deltapine-90 could not contribute any additive genes for the improvement of fiber quality traits like Uhml, strength and uniformity. It had one of the lowest means for the three traits. Breeders should look for appropriate germplasm that can contribute to the improvement of these fiber quality traits. Delcero should be backcrossed, with high yielder inbred lines to transfer its main fiber quality trait like fiber strength and length. Thus, these inbred lines could be potential varieties for future use by combining important quality traits through back crossing.

1. INTRODUCTION

Cotton (*Gossypium spp*) is the leading natural fibre crop and second most important oilseed crop in the world (Fryxell, 1992). The green revolution was mainly attributed the development and adoption of high yielding varieties in grain crops. However, a similar revolution in cotton was ushered by the introduction of inter- and intra-specific hybrids. Improvements in textile processing, particularly advances in spinning technology, have led to increased emphasis on breeding cotton for both improved yield and improved fiber properties in the world (Patil and Singh, 1995).

Cotton production and weaving has a very long history in Ethiopia. It has played an important role as a means of livelihood for craftsmen involved in the weaving cottage industry. It has also been contributing a lot for the development of textile industries and offering considerable employment opportunities in the textile mills and in the farms (Bateno, 2004).

Currently, the country's textile industry parks are booming in an alarming rate to use cotton fiber as a major source of raw material but the production and productivity of cotton has been constrained by lack of high yielding varieties with higher fiber quality traits, insect pest and disease management techniques, crop management practices and biotic and abiotic stresses.

The world average cotton lint productivity is 780kg/ha (2167kg/ha raw seed cotton) and the national average lint yield is 612 kg/ha (1700kg/ha raw seed cotton) (NCRS, 2017). Delecero which is a parental genotype has acceptable high fiber quality traits but its seed cotton and lint yield productivity is not higher than the parental genotype Deltapine-90. Thus, it has not yet been commercialized but crossed with other genotypes to combine its high fiber quality traits with other high yielder genotypes like Deltapine-90.

The cotton varieties widely grown in Ethiopia are primarily Deltapine-90 and Acala- SJ2 (American varieties). However, these varieties have been used for more than 20 years, thus giving rise to the serious problem of variety ageing and degeneration. Generally, a variety is being limited to 3-5 year's use in the major cotton producing countries, because by renewal of species, yield can be increased by l0%-15%., in some cases, even by 30% (Chavan, 2010).

As of 1928 in Ethiopia, research on cotton improvement has been mainly made to develop high yielding and high fiber quality cotton varieties for production. So far twenty one varieties, seven hybrids and two transgenic varieties have been released for irrigated areas and five varieties have also been released for rain fed areas (WARC, 2018). Almost all of the cotton varieties released so far fulfilled the world acceptable fiber quality standards. World acceptable fiber quality standards as per parameter wise are; fiber length >27.4mm; Strength >28gram/tex and Microaire 3.5-4.9 (Pretorius *et al*., 2015).

In order to meet the evolving demands of the producers and domestic textile mills and foreign market, high yielding and better fiber quality varieties must be generated in a continuous basis**.** This experiment was conducted with the objective of evaluating and selecting superior segregating cotton genotypes under irrigated condition.

MATERIALS AND METHODS

Description of the testing Site

The study was conducted at Werer Agricultural Research Center (WARC), Amibara District, Gebiresu zone of Afar National Regional State during 2016 cropping season (May to November, 2016). The altitude of Werer is 740 m.a.s.l. The average maximum and minimum temperature of Werer is 34℃ and 19℃ , respectively. The average rainfall of Werer is about 571 mm annually which is erratic in its nature. The main water source for crop production in this region is irrigation water from Awash River. The soil is predominantly vertisol with porosity and bulk density (0-25cm depth) of 49.06% and 1.3 5gm/cm^2, respectively (Wendemagegn & Abere, 2012).

Experimental Materials and Design

Fourteen *Gossypium hirsutum* F_5 lines obtained from a cross between Deltapine-90 and Delcero were used for the study along with the two parents (Table 1). The two parents are pure lines that have been maintained in the breeding program at WARC through frequent selfing.Deltapine-90, for its high yield while Delcero for its lint quality were selected.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Each treatment had five rows, each five meters long with spacing of 90 cm between rows and 20cm between plants. The plot size was 5 x 5m x 0.9m =22.5m^2. Net plot size was 3 rows x 5m x 0.9m=13.5 m^2

Table 1. List of Cotton genotypes used in the study and their pedigree

Treatment No.	Treatment code	Treatments/pedigrees
1	A	Delcero X Deltapine-90 #F5-5-3-2-1-1
2	B	Delcero X Deltapine-90 #F5-5-3-2-2-1
3	C	Delcero XDeltapine-90 #F5-5-3-2-2-Bulk
4	D	Delcero XDeltapine-90 #F5-5-3-3-1-1
5	E	Delcero XDeltapine-90 #F5-5-3-3-1-2
6	F	Delcero X Deltapine-90 #F5-5-4-2-1-Bulk
7	G	Delcero X Deltapine-90 #F5-5-4-2-2-1
8	H	Delcero X Deltapine-90 #F5-5-4-2-3-2
9	I	Delcero X Deltapine-90 #F5-5-4-2-3-3
10	J	Delcero X Deltapine-90 #F5-5-4-2-3-Bulk
11	K	Delcero X Deltapine-90 #F5-5-4-3-1-Bulk
12	L	Delcero XDeltapine-90 #F5-5-4-3-2-1
13	M	Delcero X Deltapine-90 #F5-5-4-3-3-Bulk
14	N	Delcero XDeltapine-90 #F5-5-7-1-1-1
15	O	Deltapine-90 (Parental line)
16	P	Delcero (Parental line)

Management Practices

Management practices including land preparation, irrigation, weeding, hoeing, and insecticide application were applied as per recommended package for cotton. Two seeds per hole have been planted to ensure maximum germination. Thinning was conducted after two weeks of germination to ensure single plant per hill. Earthing up (piling up soil around plants in a row to avoid lodging) was made when the cotton plants reached at squaring stage. Hoeing has been done three times. The trial has been kept weed free by hand weeding and it was irrigated four times using furrow irrigation scheme. Seed cotton yield was picked twice by hand.

Data Collection

In each plot fifteen competitive plants were randomly taken from the middle three rows and observations were made for phenology, growth parameters, yield and yield related traits. Physical fiber quality parameters were also measured. The description of the measured parameters/traits is given as follows.

3.5.1. Crop phenology

Days to emergence (DTE): Days to emergence was recorded as the number of days from date of sowing to date of 50% seedling emergence in each plot.

Days to initial squaring (DIS): Days to initial squares was recorded as the number of days from date of emergence to the date of appearance of the first floral bud, that is, small green, pyramidal structure known as square on the predetermined samples in each plot.

Days to initial flowering (DIF) and **Days to initial boll opening (DIBO)**: were recorded as the number of days from date of seedling emergence to date of appearance of the first bloom (flower) and the first open boll respectively.

Days to 50% flowering (D50F): The number of days was recorded from seedling emergence to the appearance of flowers on about 50% of the plants out of the predetermined sample plants in each plot.

Days to first picking (D65BO): Days to first picking was determined as the number of days from seedling emergence to 65% boll opening for each genotype per plot. To determine 65% boll opening of each genotype per plot, the total number of opened and unopened bolls of 15 sample plants had been counted. Then 65% boll opening (D65BO) was calculated as follows;

$$\%\ \text{of open boll} = \frac{\text{No of open bolls of 15 plants}}{(\text{No of opened boll} + \text{unopened boll}) \text{ of 15 plants}} * 100$$

D65BO was recorded when this percentage was equal to or greater than 65%.

3.5.2. Growth parameters

Plant height (PLH): Plant height was measured from 15 sample plants at harvesting time. The height from ground level to the top most bud of fifteen randomly selected plants from the central three rows of 15 sample plants in each plot was recorded using wooden ruler.

Number of sympodial branches per plant (SYM): Number of symbodia (fruiting branches) was counted from 15 sample plants at harvest.

Number of monopodial branches per plant (MON): Number of monopodia (vegetative branches) was counted from 15 sample plants at harvest.

Nodes to first fruiting branch (NFFB): The number of nodes was counted starting from node above cotyledon's node (excluding cotyledonary node) up to the node with first fruiting branch of 15 sample plants in each plot at harvest.

3.5.3. Yield and yield components

Boll number per plant (BOP): Number of both opened and unopened bolls on sympodial and monopodial branches was counted separately from 15 sample plants at harvest in each plot.

Boll weight (BOW): Prior to harvest, bolls on sample plants were harvested separately and retained for determination of boll weight, ginning percentage, hundred seed weight, and fiber properties. Boll weight was determined as an average weight of bolls harvested on the 15 plants in each plot.

Seed cotton yield (SCY): To obtain the seed cotton yield per plot all plants in the three middle rows were harvested and thus, seed cotton yield was determined from the harvest of net plot area of three rows (13.5 m^2), excluding two outermost rows. First and second hand picking was done on 11th November and 2nd December, 2016, respectively. Seed cotton yield harvested from sampled 15 plants was added, to this harvest. Weighing was made using sensitive electrical balance.

Ginning percentage (GP) and lint yields (LIN): Seed cotton harvested from sample plants retained from each plot was ginned on a laboratory saw gin, and the lint and seed portions were weighed to determine ginning (lint) percentage. Ginning percentage was determined as the percentage weight of lint to weight of sample seed cotton. The derived ginning percentage was then used to calculate lint yield per hectare.

$$Ginning\ percentage = \frac{sampled\ \ lint\ yield}{sampled\ seed\ cotton\ yield} \times 100$$

$$lint\ yield\ = \frac{seed\ cotton\ yield \times GP}{100}$$

Hundred seed weight (HSW): was determined by weighing 100 seeds taken randomly from the harvested net plot area.

Seed number per boll (SNPB): The average number of seeds has been taken from 30 bolls in each plot.

Stand count: Final plant population was determined at harvest by counting the number of plants on the net plot.

3.5.4. Physical fiber quality properties

Fiber quality tests were made in a controlled laboratory environment at a relative humidity of 63% and temperature of 21^{0}C to determine cotton physical fiber properties. Before testing, fiber samples were conditioned in the laboratory environment for 24 hours to bring the moisture content into a specified range before the classing process begins. Testing was conducted at Ethiopian Textile Industry Development Institute in Addis Ababa.
Measurements for upper half mean length, length uniformity; fiber strength, micronaire, color grade (degree of reflectance and yellowness) and short fiber content were performed by precise High Volume Instrument (HVI), in a process commonly referred to as "high volume instrument classification.

Fiber length (Uhml): The length is the most important attribute of the fiber. Fiber length is described as "the average length of the longer one half of the fibers (upper half mean length)".

Fiber strength (Str): Fiber strength was measured in gram per tex (g/tex). It is determined as the force necessary to break the beard of fibers, clamped in two sets of jaws. Fiber strength is the amount of force required to break a one tex unit in size (A tex unit is equal to the weight in grams of 1000 meters of fiber).

Micronaire (Mic): Micronaire measurements are a combination of fiber fineness and mmaturity. Cotton lint with micronaire below 3.5 is usually considered as immature and weak (Chaudhry and Guitchounts, 2003). Micronaire values higher than 4.9 are less desirable as the fibre becomes too coarse for spinning. Micronaire values which range between 3.5 and 4.9 are considered as fine cottons; micronaire values ranging between 4.3 through 4.9 receive a premium (Cotton Org, 2015).

Length Uniformity (Ui): Fiber uniformity is one of the three important fiber properties besides micronaire and fiber strength that determine the quality premium paid for cotton (Cotton Org, 2015). In HVI analysis fiber uniformity is the ratio between the mean length and upper half mean length of the fibers and is expressed in percentage, whereas in fibro graph estimation, it is the ratio between 2.5% span length and 50% span

length (Bradow and Davidonis, 2000).

Short fiber content (Sf): Short fibers have been defined as those measuring less than 12.7 mm in length (Bradow and Davidonis, 2000). It is the proportion of the short fiber length wich is less than 12.7mm and expressed in percent.

Color grade: is determined by the degree of reflectance (Rd) and yellowness (+b) as established by official standards and measured by the high volume instrument. Reflectance indicates how bright or dull a sample is, and yellowness indicates the degree of pigmentation. A three-digit color code is determined by locating the point at which the Rd and +b values intersect on the color chart.

Statistical Analysis

Analysis of variance

The data was subjected to analysis of variance using the general linear model (GLM) procedure of SAS (SAS Institute, 2002). Genotype effect F tests were performed against their error source. Means were separated using Fisher's **protected** least significance difference test (LSD) at p=0.05.

The ANOVA model of the data is given below at Table 2 and the linear model equation of analysis of variance is as follows:-

Yij = Mean + Blocki + Trtj + Errorij,

(Or Yij = μ + ρi + αj + eij) Mean is the overall mean (or μ**)**; Block (or ρi**)** is the random effect of the i^{th} block; Trtj (or αj**)** is the fixed effect of the j^{th} variety. Errorij (or eij**)** is the error term specific to the variety identified assigned to the j^{th} treatment within the i^{th} block.

Table 2. Analysis of variance (ANOVA) model for quantitative characters

Source of variation	DF	MS	EMS
Block (rep)	r-1	MSb	$\sigma^2e + g\sigma^2r$
Genotypes	(g-1)	MS_G	$\sigma^2e + r\sigma^2g$
Error	(g-1)(r-1)	MSe	σ^2e
Total	gb-1		

Where b = number of blocks/replications, g= number of genotypes; DF= degree of freedom, MSb= mean square of blocks, MS_G= mean square of genotypes, MSe = mean square of error,σ^2G= genotype variance components,σ^2e=error variance, σ^2g= (MSg-MSe)/r, σ^2e = MSe

RESULT AND DISCUSSION

Analysis of Variance (ANOVA)

The analysis of variance revealed that the tested genotypes differed significantly ($p<0.05$) in days to emergence (DTE), number of sympodial branches plant^{-1}(SYM), number of nodes to first fruiting branch (NFFB), Plant height (PLH), boll number plant^{-1} (BOP), Boll weight (BOW), Seed cotton yield plot^{-1} (SPO),Seed cotton yield ha^{-1} (SHA),Ginning percentage (GP), lint yield plot^{-1} (LPO) and ha^{-1}(LHA), hundred seed weight (HSW), micronaire (Mic), upper half mean length (Uhml), Short fiber content (Sf), Fiber Strength(Str), degree of reflectance (Rd) and yellowness (+b) (Table 5). This significance difference indicated that there was variability among the F5 lines in growth parameters, in lint yield and yield components and also in almost all fiber physical quality parameters; variability that can be exploited in further selection. The remaining characters showed no significant variability among the genotypes. These characters were days to initial squaring (DIS), days to 50% flowering (D50F), days to initial boll opening (DIBO), days to 65% boll opening (D65BO), number of monopodial branches plant^{-1} (MON), seed cotton yield plant^{-1} (SPL), lint yield plant^{-1} (LPL), seed number boll^{-1} (SNPB) and fiber uniformity (Ui).

Table 3. Analysis of variance

Table 3.1. ANOVA for cotton phenology

S. variation	DTE	DIS	DIF	D50F	DIBO	D65BO
Genotypes	0.474**	12.591ns	12.563ns	13.329ns	49.891ns	29.232ns
Replication	0.057	19.266	99.854	87.354	613.099	8.766
Error	0.191	7.688	9.887	16.632	66.232	19.921
CV	7.871	8.644	6.324	7.238	8.596	3.049
LSD	0.622	3.949	4.478	5.8	11.59	6.357
R-square	0.460	0.416	0.532	0.382	0.465	0.341

*, ** and *** are significance levels of p-value at 5%, 1% and 0.1%, respectively and ns= non significance, S. variation: source of variation, CV: coefficient of variability, LSD: least significance difference, DTE: days to emergence, DIS: days to initial squaring, DIF: days to initial flowering, D50F: days to 50% flowering, DIBO: Days to initial boll opening, D65BO: days to 65% boll opening

Table 3.2. ANOVA for growth parameters

S. variation	SYM	MON	NFFB	PLH
Genotypes	4.468***	0.064ns	0.163***	253.212**
Replication	2.413	0.193	0.044	336.981
Error	1.415	0.06	0.053	97.879
CV	9.397	54.88	4.54	9.646
LSD	1.694	0.348	0.328	14.09
R-square	0.538	0.364	0.519	0.522

SYM: number of Sympodial branch plant^{-1}, MON: number of monopodial branch plant^{-1}, NFFB: number of nodes to first fruiting branch, PLH: plant height (cm)

Table 3.3 ANOVA for yield and yield related traits

S. variation	BOP	BOW	SPL	SPO	SHA	GP	LPL	LPO	LHA	HSW	SNPB
Genotype	15.872***	0.665***	174.456ns	1079220.0*	591986.1*	6.454***	40.658ns	233698.902**	128217.68**	3.159***	2.673ns
Replication	9.440	0.147	217.320	517987.5	283973	1.902	25.056	48452.812	26557	0.022	6.716
Error	3.011	0.075	156.137	523814.17	287442	0.732	24.779	81177.333	44562.44	0.183	3.908
CV	11.627	5.277	13.657	11.819	11.819	2.167	13.777	11.779	11.782	4.855	6.43
LSD	2.471	0.391	17.796	1030.8	763.56	1.218	7.089	405.77	300.64	0.61	2.815
R-square	0.663	0.574	0.318	0.429	0.429	0.757	0.381	0.5	0.5	0.852	0.255

BOP: boll plant^{-1}, BOW: boll weight (g), SPL: seed cotton yield plant^{-1} (g): SPO: seed cotton yield plot^{-1} (g) SHA: seed cotton yield ha^{-1} (kg), GP: ginning percentage, LPL: Lint yield plant^{-1} (g), LPO: lint yield plot^{-1} (g), LHA: lint yield ha^{-1} (kg), HSW: hundred seed weight (g), SNPB: seed number boll^{-1}

Table 3.4. ANOVA for fiber quality traits

S. variation	Mic	Uhml	Ui	Sf	Str	Rd	+b
Genotype	0.174***	7.128**	4.722ns	3.544**	24.636***	2.033*	0.303***
Replication	0.129	0.625	1.340	1.74	0.618	1.177	0.194
Error	0.034	0.524	2.677	1.350	1.311	0.88	0.076
CV	4.1	2.465	2.01	11.553	4.142	1.139	3.263
LSD	0.263	1.031	2.33	1.655	1.631	1.336	0.393
R-square	0.661	0.822	0.383	0.49	0.863	0.462	0.6

Mic: micronaire (units), Uhml: upper half mean length (mm), Ui: length uniformity (%), Sf: short fiber content (%), Str: fiber strength (gram/tex), Rd: degree of reflectance (units), +b: yellowness (units).

One degree contrast

A one degree of contrast between the mean of the 14 F5 inbred lines and the mean of the two parents was significant for all traits except for DTE, DIF, D50F, DIBO, D65BO, MON, NFFB, PLH, SNPB, Ui, and +b (Table 4). All 14 lines included in this study were better than both parents in SYM, BOP, SHA, GP, LPL, and LHA, but were inferior to both parents in BOW, indicating that there was transgressive expression of the majority of traits (Table 5.5). Additive genes were dispersed in the two parents for these traits. The difference between Deltapine and Delecero was minimal for SYM (11.4 vs 11.4), BOP (12.57 vs 9.95); the few additive genes by which the two parents differed made large contribution to the progenies of the cross between the two parents.

There was no shift in phenology of the segregating F5 lines in phenology as compared to their parents. The difference between the two parents was also significant for most of these traits except for SYM, NFFB, SPL, SPO and SHA).

Table 4. One Degree contrast

Parameters	DTE	DIS	DIF	D50F	DIBOP	D65BO	SYM	MON	NFFB	
	Estimates									
All Vs Delatpine	4.0^{ns}	-42.5*	-20.75^{ns}	-47.75^{ns}	-33.25^{ns}	59.5^{ns}	20.44*	-1.24^{ns}	2.22^{ns}	
All Vs Delecero	-6.5^{ns}	-39.0^{ns}	-3.25^{ns}	-30.25^{ns}	-33.25^{ns}	21.0^{ns}	20.44*	1.35^{ns}	1.77^{ns}	
All Vs Parents	-1.25^{ns}	-40.75**	-12.0^{ns}	-39.0^{ns}	-33.25^{ns}	40.25^{ns}	20.44**	0.053^{ns}	1.99^{ns}	
Parameters	PLH	BOP	BOW	SPL	SPO	SHA	GP	LPL	LPO	
	Estimates									
All Vs Delatpine	177.013*	40.31**	2.78^{ns}	222.87*	10430.0*	77.29*	15.98*	102.23**	5108.9*	
All Vs Delecero	-69.11^{ns}	76.95**	-17.73**	121.33^{ns}	18410.0**	136.37**	59.24**	97.14**	10189.12**	
All Vs Parents	53.95^{ns}	58.63**	-7.47**	172.1*	14420.0**	106.83**	37.61**	99.71**	7649.01**	
Parameters	LHA	HSW	SNPB	Mic	Uhml	Ui	Sf	Str	Rd	+b
	Estimates									
All Vs Delatpine	37.85*	1.19^{ns}	7.21^{ns}	0.51^{ns}	18.29**	14.05^{ns}	-1.9^{ns}	19.25*	3.78^{ns}	-1.4^{ns}
All Vs Delecero	75.48**	-46.13**	-2.39^{ns}	9.51**	-52.06**	-34.6**	31.0**	-128.45**	23.38**	2.1^{ns}
All Vs Parents	56.66**	-22.47**	2.41^{ns}	5.01**	-16.89**	-10.28^{ns}	14.55*	-54.6**	13.58**	0.35^{ns}

*, ** and *** are significance levels of p-value at 5%, 1% and 0.1%, respectively and ns: non significance, S. variation: source of variation, CV: coefficient of variability, LSD: least significance difference, DTE: days to emergence, DIS: days to initial squaring, DIF: days to initial flowering, D50F: days to 50% flowering, DIBO: Days to initial boll opening, D65BO: days to 65% boll opening, SYM: Sympodial branch plant^{-1}, MON: monopodial branch plant^{-1}, NFFB: number of nodes to first fruiting branch, PLH: plant height (cm), BOP: boll plant^{-1}, BOW: boll weight (g), SPL: seed cotton yield plant^{-1} (g): SPO: seed cotton yield plot^{-1}(g), SHA: seed cotton yield ha^{-1}, GP: ginning percentage, LPL: Lint yield plant^{-1} (g), LPO: lint yield plot^{-1}(g), LHA: lint yield ha^{-1} (kg), HSW: hundred seed weight (g), SNPB: seed boll^{-1}, Mic: micronaire (units), Uhml: upper half mean length (mm), Ui: length uniformity (%), Sf: short fiber content (%), Str: fiber strength (gram/tex), Rd: degree of reflectance (units), +b: yellowness (units).

Mean comparison for quantitative traits

Deltapine being superior to Delecero in BOP (12.57 vs 9.95), GP (38.7 vs 35.6%) and LPO (2122.2 vs 1759.4 g) or LHA (1572 vs 1303 kg), Deltapine emerged earlier than Delecero (5.25 vs 6.0 days), was inferior in PLH (90.4 vs 108cm), BOW (4.9 vs 6.4 g) and HSW (8.5 vs 11.9 g). The superiority of Deltapine over Delecero in Lint yield ha^{-1} emanated from its higher boll number $plant^{-1}$ and its higher ginning percentage; it was inferior to Delecero in boll weight. The seed cotton yields of Deltapine and Delecero were not statistically different (4.08 vs 3.66 t ha^{-1}).

The mean of the 14 lines was higher than the mean of the two parents and the mean of the highest value and the mean of the two parents by 12.8% and 34.0% in SYM, by 37.2 and 56.0% in BOP, by 19.7 and 26.7% in SHA, and by 28.1 and 45.5% in LHA. The line with the highest value was superior to the parent with the highest value by 34% in SYM (line 9 (15.25 vs 11.38), by 39.94% in BOP (Line 9; 17.59 vs 12.57), by 26.7% in SHA (Line 11; 51.7 vs 40.8), by 33.1% in LHA (Line 11; 20.92 vs 15.72). None of the inbred lines were superior to Delecero in BOW (6.41 g) and in HSW (11.92 g). The mean of the 14 lines (5.14) was inferior to the mean of the two parents by 9.3% and by 20.1% to that of Delecero (6.41 g). The line with the highest BOW (Line 8; 5.42 g) was inferior to Delecero by 15.4% in BOW.

Phenology

As the mean separation result presented at Table 5a below, the phenology parameter viz., DTE, had significant mean differences between the genotypes.

Days to emergence (DTE)

Separate mean analysis of DTE indicated that genotypes B, C, D, E, F, J, K L, M, N and P had first ranked in same group at LSD 0.622. These genotypes indicated as they have satisfied days to emergence at 50% scoring equally. The genotypes emerged delayed as compared to the remaining genotypes. Genotypes A, G, H, I and O categorized by other group and stood last in rank compared to others but emerged earlier than others. The minimum and maximum day taken to emerge for the tested genotypes was 5 to 6. It is a day difference and was not considerable. This study confirmed that under favorable conditions, the radicle (root tip) emerges within 2-3 days from the seed and newly germinated seedlings emerge above the soil 5-6 days after emergence of the radicle (Oosterhuis and Jernstedt, 1999).

Growth parameters

Sympodial branches (SYM)

As depicted at Table 5a of mean analysis number of sympodial branches ranged from minimum 10.93 (A) to maximum 15.25 (I). Genotypes K (13.67), F (13.32), M (13.2), B (13), H (12.99), L (12.97) and E (12.9) had highest branch count comparing to the remaining genotypes (Table 6a).

Number of nodes to first fruiting branch (NFFB)

The mean separation analysis of genotypes for number of nodes to first fruiting branch ranged from 4-5. This indicated that all genotypes have been categorized under early maturing types.

Plant height (PLH)

The maximum plant height was recorded relatively for the genotypes I (115.48cm), J (114.59cm), K (112.2cm), G (106.7cm), H (106.35cm), M (105.53cm), N (103.73cm), while the minimum plant height was recorded for the genotypes F (89.43cm), O (90.40cm), E (94.97cm) and D (96.37cm) (Table 5a). There was significant mean difference at LSD (14.09) between inbred lines and the parent. The mean difference between the highest plant height of inbred lines viz., I (115.48cm), J (114.59cm), K (112.2cm), G (106.7cm), H (106.35cm), M (105.53cm) and parent O (90.40cm) (Table 5a). But parent P (107.98cm) compared with inbred lines haven't showed significance mean difference at LSD (14.09).

Table 5. Mean comparisons

Table 5a. Mean for phenology, growth parameters and yield and yield related components

Genotypes	DTE	SYM	NFFB	PLH	BOP	BOW
A	5.25^{bc}	10.93^{e}	5.23^{bdac}	101.53^{ebdac}	14.60^{de}	4.52^{f}
B	5.75^{ba}	13.0^{bcd}	4.73^{g}	97.29^{edc}	15.25^{bdac}	5.4^{b}
C	5.5^{bac}	11.94^{ecd}	4.85^{egf}	97.39^{edc}	14.82^{dec}	5.16^{cbd}
D	5.75^{ba}	11.68^{ecd}	4.90^{edf}	96.37^{edc}	13.72^{de}	5.32^{cbd}
E	5.5^{bac}	12.9^{bcd}	4.78^{gf}	94.97^{edc}	13.95^{de}	5.33^{cb}
F	6.0^{a}	13.32^{bc}	4.98^{ebdgcf}	89.43^{e}	14.25^{de}	5.31^{cbd}
G	5.0^{c}	12.29^{becd}	5.3^{ba}	106.7^{bac}	17.1^{bac}	5.11^{cbd}
H	5.25^{bc}	12.99^{bcd}	5.27^{bac}	106.35^{bac}	13.99^{de}	5.42^{b}
I	5.0^{c}	15.25^{a}	5.08^{ebdacf}	115.48^{a}	17.59^{ba}	5.21^{cbd}
J	6.0^{a}	12.87^{bcd}	5.17^{ebdac}	114.59^{ba}	17.29^{bac}	5.36^{b}
K	5.5^{bac}	13.67^{ba}	5.30^{ba}	112.2^{ba}	17.57^{a}	5.09^{cbd}
L	6.0^{a}	12.97^{bcd}	5.37^{a}	101.1^{ebdc}	16.02^{bdac}	5.08^{cebd}
M	5.5^{bac}	13.2^{bc}	5.25^{bdac}	105.53^{bac}	15.08^{bdc}	4.96^{ced}
N	5.5^{bac}	12.8^{bcd}	5.10^{ebdacf}	103.73^{bdac}	15.12^{bdac}	4.69^{ef}
O	5.25^{bc}	11.38^{ed}	4.94^{edgf}	90.40^{ed}	12.57^{e}	4.94^{ed}
P	6.0^{a}	11.38^{ed}	4.97^{edgcf}	107.98^{bac}	9.95^{f}	6.41^{a}
LSD	0.62	1.69	0.33	14.09	2.47	0.39

DTE: days to emergence, SYM: Sympodial branch plant^{-1}, NFFB: number of nodes to first fruiting branch, PLH: plant height (cm), BOP: Boll plant^{-1}, BOW: boll weight (g)

Yield and Yield components

Boll number per plant (BOP)

As depicted at Table 5a inbred lines had significant mean difference for boll number per plant viz., I (17.59), K (17.57), J (17.29), G (17.1), L (16.02), B (15.25), N (15.12), M (15.08) with parents O (12.57) and P (9.95) at LSD value 2.47. The inbred lines revealed superior performance in boll retention per plant. Thus, it is the cause for better yield performance of the inbred lines than the parents.

Boll weight (BOW)

The maximum boll weight was recorded for the parent P (6.41g) and the minimum was recorded for inbred line A (4.52g) (Table 5a). The weight of the genotypes under study ranged from 4.52-6.41g. The inbred lines B (5.39g), H (5.42g) and J (5.36g) had significance mean difference with parent O (4.94g) at LSD of 0.39.Thus; this inbred lines superior than parent O but not P.

Seed cotton yield and lint yield

As presented at Table 5b the relative mean performance of the genotypes, inbred line K had the highest seed cotton yield (5170.3 kgha^{-1}) and lint yield (2091.8 kgha^{-1}), respectively. The inbred line K had surpassed the parents O (Deltapine-90) and P (Delcero) with a yield difference of 1090.8 kgha^{-1} (26.7%) and 1512.5 kgha^{-1} (41.4%) in seed cotton yield, respectively. This inbred line also had better performed than the parents Deltapine-90 and Delcero in lint yield ha^{-1} with a difference of 519.8 kg (33.1%) and 788.5 kg (60.5%), respectively.

The second inbred line that showed better performance than others was G which had 5072.0 and 1999.3 kgha^{-1} seed cotton yield and lint yield, respectively. This genotype exceeded the parents O and P with an advantage of 992.5 and 1414.5 kgha^{-1} seed cotton yield and 427.3 and 696 kgha^{-1} lint yield, respectively. The third superior inbred line was I and it had 4987 kgha^{-1} seed cotton yield and 1953.5 kgha^{-1} lint yield which excelled the parent O and P by 907.5 and 1329.5 kgha^{-1} seed cotton yield ; 381.5 and 650.2 kgha^{-1} lint yield, respectively. Most of the inbred lines excelled their parents for seed cotton yield and lint yield performance. Among the best inbred lines that surpassed the parents on seed cotton yield are: K, G and I, and better than the released varieties viz., Sisikuk-02 (4070 kgha^{-1}), Werer-50 (4300 kgha^{-1}) and Weyto-07 (4620 kgha^{-1}) (WARC, 2018). These inbred lines have also exceeded the national average seed cotton yield of

Ethiopia which ranged from 2000 to 3000 kgha^{-1} and 700 to 1400 kgha^{-1} under irrigated and rain fed conditions, respectively. Thus, these inbred lines could be potential varieties for future use. The genetic gain obtained on most of the inbred lines was more than 10% in both seed cotton yield and lint yield.

Table 5b. Mean for phenology, growth parameters and yield and yield related components

Genotypes	SPO	SHA	GP	LPO	LHA	HSW
A	5572.5^{dc}	4128.0^{dc}	41.535^{a}	2314.9^{bc}	1714.8^{bc}	7.53^{b}
B	6185.0^{bac}	4581.8^{bac}	39.33^{edc}	2427.1^{bac}	1798^{bac}	8.72^{b}
C	6370.0^{bac}	4718.5^{bac}	39.89^{bdc}	2542.5^{ba}	1883.3^{ba}	8.55^{b}
D	6040.0^{bac}	4474.0^{bac}	39.62^{bedc}	2392.8^{bc}	1772.5^{bc}	8.62^{b}
E	6140.0^{bac}	4548.3^{bac}	38.83^{ed}	2384.0^{bc}	1766^{bc}	8.85^{b}
F	5885.0^{bdc}	4359.3^{bdc}	39.65^{bedc}	2338.3^{bc}	1732^{bc}	8.62^{b}
G	6847.5^{ba}	5072.0^{ba}	39.41^{edc}	2698.8^{ba}	1999.3^{ba}	8.85^{b}
H	6142.5^{bac}	4550.3^{bac}	39.99^{bdc}	2457.1^{bac}	1820.3^{bac}	8.99^{b}
I	6732.5^{ba}	4987.0^{ba}	39.18^{ed}	2637.2^{ba}	1953.5^{ba}	8.86^{b}
J	6417.5^{bac}	4753.8^{bac}	39.61^{bedc}	2530.2^{ba}	1874.3^{ba}	8.71^{b}
K	6980.0^{a}	5170.3^{a}	40.48^{bac}	2824.1^{a}	2091.8^{a}	8.47^{b}
L	6325.0^{bac}	4685.3^{bac}	39.85^{bedc}	2520.5^{bac}	1867^{bac}	8.44^{b}
M	5872.5^{bdc}	4350.3^{bdc}	40.79^{ba}	2396.6^{bc}	1775.5^{bc}	8.66^{b}
N	6025.0^{bac}	4463.0^{bac}	39.1^{ed}	2356.0^{bc}	1745^{bc}	8.82^{b}
O	5507.5^{dc}	4079.5^{dc}	38.66^{e}	2122.2^{dc}	1572^{dc}	8.54^{b}
P	4937.5^{d}	3657.5^{d}	35.57^{f}	1759.4^{d}	1303.3^{d}	11.92^{a}
LSD	1030.8	763.56	1.218	405.77	300.64	0.61

SPO: seed cotton yield plot^{-1} (g), SHA: seed cotton yield ha^{-1}, GP: ginning percentage, LPO: lint yield plot^{-1} (g), LHA: lint yield ha^{-1} (kg), HSW: hundred seed weight (g)

Fiber quality traits

Deltapine was superior to Delecero in Mic (4.52 vs 3.88), had higher Sf (10.33 vs 7.98%; higher short fiber percentage; actually it was inferior), and had higher Rd (82.23 vs 80.83), but was inferior to Delecero in Uhml (27.90 vs 32.92), Ui (80.4 vs 83.88), and in Str (25.78 vs 36.33). The higher fiber quality of Delecero was expressed in its higher Uhml, strength, and its lower percentage of short fiber content (Sf, 8.0%) (Table 6).

All the 14 F5 lines were inferior to Delecero in Uhml, strength and uniformity although all
fulfilled the minimum criteria for Uhml (>25 mm, 26.9 of line 1 to 32.9 mm of Delecero), Mic (between 3.9 of Delecero and 4.8 of line 13; all higher than 3.5 and lower than 4.9, i.e., in the range of “Fine fiber)), Str (>25.0) and Sf (<14%). Deltapine could not contribute any additive genes for the improvement of fiber quality traits like Uhml, strength and uniformity. It had one of the lowest means for the three traits. Breeders should look for appropriate germplasm that can contribute to the improvement of these fiber quality traits. Seven lines had higher Micronnaire than Deltapine, while 12 lines surpassed Deltapine in degree of reflectance (Rd).

The accepted standard values for the different fiber qualities are as follows: length > 27.4 mm, strength > 28 g/tex, and micronaire 3.5 - 4.9 (Pretorius et al., 2015). According to Chaudhry and Cuitchounts (2003) cotton lint with micronaire below 3.5 is usually considered immature and weak whereas micronaire values higher than 4.9 are less desirable as the fiber becomes too coarse for spinning.

Micronaire (Mic)

Among the tested genotypes for micronaire inbred line M (4.79) performed the highest value. According to Cotton Org (2015), micronaire values which ranges between 3.5 and 4.9 are considered as fine cotton and micronaire values ranging between 4.3 to 4.9 receive a premium price. Thus, all the inbred lines, receive a premium price since it ranged 4.38 and 4.79, while the parents was exhibited 3.88 for Delcero and 4.52 for Deltapine-90. The inbred lines had better out performed than the parents. The difference from the parents, Deltapine-90 and Delcero was 0.27 and 0.91, respectively. According to Ethiopian grading standards the best quality is ranged from 3.5-4.2 and given ‘A’ grade and sold at premium price US $1.47/kg. Thus the parent P has obtained an

advantage over the other inbred lines to be preferred. The second inbred line which excelled in micronaire value was B (4.75) and the difference from its parents O and P was 0.23 and 0.87, respectively. The third genotype that yielded the maximum micronaire was D (4.69). This genotype had surpassed the parents O (Deltapine-90) and P (Delcero) in micronaire by 0.17 and 0.82, respectively. The genetic gain has been obtained from the inbred lines when compared to parents for micronaire. However, the genetic gain obtained was sufficient in number as compared to the parent Deltapine-90 and Delcero, its quality was low because the acceptable micronaire quality receiving "A" grade ranged from 3.5 to 4.2.

Ethiopia has declared cotton quality specification, grading and local trading price based on this specification staple length, micronaire, strength, short fiber content, length uniformity ratio, color and proposed buying price of lint cotton US $/ kg (USDA,2016). Based on this specification grading all of the inbred lines in this experiment for micronaire (4.3 to 4.9) had fallen at "B" grade. Parent P (Delcero) was the only genotype that had 3.88 micronaire value found in between 3.5-4.2 and receiving "A" grade (Appendix Table 2).

Upper Half Mean Length (Uhml)

As presented at Table 6 inbred line I (30.34 mm), had the highest upper half mean length compared to the inbred lines. The inbred lines ranged 26.87 mm (A) to 30.34 mm (I), while the parents have had 27.9 mm (O) to 32.92 mm (P). The difference between I with its parent O and P was 2.44 and -2.58, respectively. The parent P (32.92 mm) had maximum fiber length as compared to all genotypes tested. The inbred line L (30.32 mm) was found to be the second in fiber length. The mean difference with its respective parents Deltapine-90 and Delcero was 2.42 and -2.60, respectively.

The inbred line N (30.16 mm) was the third among the inbred lines examined in this study for upper half mean length and it diverged from the parents Deltapine-90 and Delcero with 2.26 mm and -2.76 mm, respectively.

Although, parent P was superior, the genetic gain obtained for upper half mean length is good and encouraging that provides the chance to choose the best inbred lines. Parent P had the highest upper half mean length among the genotypes tested and none of the recombinant inbred lines surpassed this parent in fiber strength. Thus, this parent can still be used as a good parent for crossing aimed at improving fiber length.

Based on Appendix Table 2 of specification grading upper half mean length most of the inbred lines studied, have met the fiber quality standards set by Ethiopian textile industry development institute for staple length except inbred line A and C, had above 28.5 mm and have fallen at "A" grade which can be sold by Ethiopian premium price set $1.47/kg. The parent O had 27.9 mm which has been categorized at grade "B" priced $1.43/kg.

World acceptable fiber length standard is greater than 27.4 mm as described by Pretorius *et al*. (2015) and all the genotypes, except genotype A (26.87 mm), agrees with this standard.

Table 6. Mean for fiber quality traits

Genotypes	Mic	Uhml	Sf	Str	Rd	+b
A	4.52^{bdc}	26.87^{f}	8.65^{dc}	25.6^{g}	80.75^{c}	8.70^{a}
B	4.75^{ba}	29.13^{cd}	9.53^{bdc}	27.08^{fcebdg}	82.75^{ba}	8.175^{fde}
C	4.59^{bdac}	27.93^{e}	11.35^{a}	25.88^{fg}	82.6^{ba}	8.20^{fdec}
D	4.69^{bac}	28.66^{ed}	10.93^{ba}	26.8^{fcedg}	82.28^{ba}	7.90^{f}
E	4.68^{bac}	28.78^{ced}	9.35^{bdc}	26.33^{feg}	82.83^{ba}	8.25^{fbdec}
F	4.59^{bdac}	29.08^{cd}	10.53^{ba}	27.1^{fcebdg}	82.85^{ba}	8.03^{fe}
G	4.39^{d}	29.78^{cb}	10.90^{ba}	27.65^{cebd}	83.03^{ba}	8.55^{bdac}
H	4.53^{bdac}	29.63^{cbd}	9.88^{bac}	26.88^{fcebdg}	82.88^{ba}	8.80^{a}
I	4.49^{bdc}	30.34^{b}	9.55^{bdc}	27.68^{cebd}	82.3^{ba}	8.80^{a}
J	4.46^{dc}	29.49^{cbd}	10.55^{ba}	28.13^{cbd}	82.38^{ba}	8.73^{a}
K	4.44^{dc}	29.35^{cbd}	11.45^{a}	27.45^{fcebd}	83.25^{a}	8.45^{bdac}
L	4.48^{dc}	30.32^{b}	10.38^{ba}	28.4^{cb}	82.28^{ba}	8.60^{ba}
M	4.79^{a}	29.35^{cbd}	10.0^{bac}	28.5^{b}	81.9^{bc}	8.58^{bac}
N	4.38^{d}	30.12^{b}	9.63^{bdc}	26.65^{fedg}	82.88^{ba}	8.55^{bdac}
O	4.52^{bdc}	27.90^{fe}	10.33^{ba}	25.78^{g}	82.23^{ba}	8.55^{bdac}
P	3.88^{e}	32.92^{a}	7.98^{d}	36.33^{a}	80.83^{c}	8.30^{bdec}
LSD	0.26	1.03	1.66	1.63	1.34	0.39

Mic: micronaire (units), Uhml: upper half mean length (mm), Sf: short fiber content (%), Str: fiber strength (gram/tex), Rd: degree of reflectance (units), +b: yellowness (units)

Fiber Bundle Strength (Str)

Among the inbred lines M (28.50 gram/tex) exhibited, the maximum fiber strength, while the minimum value was obtained from inbred line A (25.6 gram/tex). The parents have had 25.78 gram/tex (O) to 36.33 gram/tex (P), fiber strength. The difference between the maximum inbred line value (M) with its parent O and P was 2.73 gram/tex and -7.83 gram/tex, respectively. The genetic gain obtained was positive relatively for O (O is inferior to M) and negative for P (P is superior to M). This indicated that P had the highest fiber strength value among the genotypes tested and none of the recombinant inbred lines surpassed this parent in fiber strength.

The second genotype among inbred lines which exhibited the highest fiber strength was L (28.40 gram/tex). The difference with its respective parents O and P was 2.63 gram/tex and -7.93 gram/tex, respectively. The third inbred line which showed highest fiber strength was J (28.13 gram/tex) and had a difference of 2.35 gram/tex and -8.20 gram/tex with its parents O (Deltapine-90) and P (Delcero), respectively.

Based on cotton quality specification, grading and local trading price of the country, most of the inbred lines studied exhibited 26-28.9 gram/tex and categorized at "B" grade which can be sold at a price of $1.43/kg.

But the parent Delcero which have had 36.33 gram/tex maximum quality and can be categorized at "A" grade (Appendix Table 2).

Among the inbred lines, only J, L and M and the parent p (Delcero) have met the world acceptable fiber strength as described by Pretorius *et al*.,(2015) which is greater than 28 gram/tex.

CONCLUSION

Keeping in view the need to develop suitable varieties of cotton, a valuable fiber rich crop, despite cotton processing factories are underway its production and productivity is declining in Ethiopia. The present study was an attempt to find superior segregating inbred lines of upland cotton existing in Werer Agricultural Research Center (WARC). To generate these information two parents and fourteen inbred lines were evaluated in WARC, on RCBD design with four replications. Data on crop phenology, growth parameters, yield and yield component traits, and physical fiber quality parameters, totally 26 traits has been recorded. The analysis of variance revealed that the tested genotypes differed significantly for most of the traits except days to initial squaring, days to 50% flowering, days to initial boll opening, days to 65% boll opening, monopodial branches, seed cotton yield per plant, lint yield per plant, seed number per boll and length uniformity.

The mean separation analysis of seed cotton yield revealed superior inbred lines that excelled their parents viz., K (5170.3kg/ha), G (5072 kg/ha) and I (4987 kg/ha). Lint yield per hectare for these inbred lines were also had similar fashion as their seed cotton yield per hectare.

In conclusion, the present study has highlighted the existence of superior inbred lines for the traits under study of upland cotton. Although the study was based on the germplasm existing at WARC, it has indicated that moderate potential to improve the lint yield per unit area.

The information obtained about can be exploited in formulating selection programme for synthesis and development of new cotton genotypes with improved yield and yield contributing traits.

Recommendations

In the present study variance component for lint yield among the 16 genotypes has suggested that introduction, collection and extensive hybridization of cotton in Ethiopia is a crucial task to enhance genetic variability. This will help to increase genetic variability and to increase the chance for selecting and developing high yielding varieties, hybrids and acceptable fiber quality standards. Delcero should be backcrossed, with high yielder inbred lines to transfer its main fiber quality trait like fiber strength and length. Thus, these inbred lines could be potential varieties for future use by combining important quality traits through back crossing.

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APPENDIX

Table 1. Cotton varieties released by WARC since 1966

No		Released year	SCY t/ha	GOT	Mic Mg/inch	FL mm	Str lb/sq inch	Recommended for
1	A-333-57	1960s	2.93	34.6		-	-	rain fed
2	Acala 1517/70	1975	3.89	36.7		-	-	Irrigated
3	Albar 637	1960s	2.06	34.8		-	-	rain fed
4	Acala 1517C	Before1970	-	37.2		-	-	Irrigated
5	Acala 1517D	Before1968	-	-		-	-	Irrigated
6	AMS1(70)	1974	2.59	37.6		-	-	Irrigated
7	Werer 1-84	1984	2.86	37.8		-	-	Irrigated
8	La Okra Leaf 2	1986	2.73	38.0		-	-	Irrigated
9	Acala 4.42	1974	2.35	38.6		-	-	Irrigated
10	Reba B-50	1960s	1.80	36.3		-	-	rain fed
11	Acala SJ2	1986	3.25	34.2	3.2	28.6	79.3	Irrigated
12	Arba	1987	3.00	40.1	3.5	30.2	79.7	rain fed
13	Bulk 202	1989	3.34	41.0	3.5	28.1	78.3	rain fed
14	Deltapine- 90	1989	3.86	34.8	3.7	27.7	77.3	Irrigated
15	Cucurova 1518	1994	4.17	38.9	3.8	26.9	74.6	Irrigated
16	Cu-Okra	1994	3.76	38.9	4.0	26.1	75.7	Irrigated
17	Carolina queen	1994	4.18	39.6	3.8	27.2	77.6	Irrigated
18	Sille-91	1997	3.86	39.4	3.6	27.9	72.7	Irrigated
						gram/tex		
19	Stam59A	2007	3.34	42.0	4.3	29.8	32.5	Irrigated
20	YD-206	2011	4.20	37.2	3.5	34.4	36.5	Irrigated
21	YD-223	2011	4.13	37.5	3.4	33.8	36.6	Irrigated
22	YD_211	2011	4.22	35.9	3.3	34.2	36.6	Irrigated
23	YD-670	2013	4.00	37.1	3.5	32.0	34.8	Irrigated
24	YD-195	2013	3.37	39.2	3.5	31.7	35.2	Irrigated
25	VBCHB 1203	2013	2.47	36.6	2.9	30.7	32.2	Irrigated
26	VBCH 1527	2013	2.43	29.0	3.6	29.9	34.0	Irrigated
27	STG-14	2014	3.88	42.7	4.22	30.0	31.7	Irrigated
28	Candia	2014	4.06	44.1	4.1	29.0	30.20	Irrigated
29	Claudia	2014	3.84	45.7	4.36	30.9	32.4	Irrigated
30	Gloria	2014	4.26	43.0	4.1	29.4	31.96	Irrigated
31	Sisikuk-02	2015	4.07	44.8	4.3	28.8	25.9	Irrigated
32	Werer-50	2015	4.30	39.0	3.9	27.7	29.5	Irrigated
33	Weyto-07	2015	4.62	38.2	3.9	26.1	29.5	Irrigated
34	JKCH 1050	2018	3.05	39.23	3.95	28.44	28.59	Irrigated
35	JKCH 1947	2018	3.06	39.37	4.06	27.78	27.75	Irrigated

SCY: seed cotton yield, GOT: ginning out turn, Mic: micronaire (mg/inch), FL: fiber length (mm), Str: trength (gram/tex)

Table 2. Cotton quality specification, grading and local trading price

S/N	Specifications	Grade		
		A	B	C
1	Staple length(mm)	≥28.5	27–28.5	25-27
2	Micronaire	3.5-4.2	4.3-4.9	3.2-3.4 and 5-
3	Strength (gram/tex)	≥ 29	26-28.9	25-25.9
4	Average sticky point	0-10	11-20	21-32
5	Short fiber content	≤ 10%	11-12%	13-14%
6	Trash content	Less than 3.5%	3.5-4.5%	4.6-5.0%
7	Moisture content	≤ 8%	≤ 8%	≤ 8%
8	Maturity ratio	≥ 85%	81-84%	75-80%
9	Length Uniformity	≥83%	81-82%	76-80%
10	Color	11-1 up to 21-4	31-1 up to 31-4	41-1 up to 51-4
11	Contamination	≤ 5 grams/bale	5-10 grams	10-15 grams
Proposed buying price of lint cotton (US $ kg^{-1})		1.47	1.43	1.40

Source: USDA, 2016

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