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Performance and Yield Advantages of Experimental Cotton (*Gossypium hirsutum* L.) Varieties over the Standard Checks in North-Western Ethiopia

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ABSTRACT

Twelve advanced upland cotton (*Gossypium hirsutum* L.) experimental lines and two check varieties were evaluated for ten phonological and agronomic traits at Kamashi, Benishangul-Gumuz Regional State during the 2017/18 main cropping season. The objective of the study was to assess performance of the experimental cotton varieties for seed cotton and lint yield. The varieties differed significantly for most of the traits with wide ranging mean values for most of the characters thus indicating the existence of variations among the tested lines and for possibility of immediate commercial utilization and for improvements in future cotton breeding programs.

INTRODUCTION

Cotton (*Gossypium spp.*), known as white gold and king of fiber crops, is one of the most important commercial cash and industrial crops in the world. Cotton is among the first crops in which the rediscovered Mendelian principles were applied (Balls, 1907). Cotton has a predominant status among all the commercial crops providing cotton fiber for the textile industry. It is also valued for the protein and oil portion of the seed. The protein portion of the seed is mainly utilized for cattle feed while the oil portion is utilized as a vegetable oil for the food industry and industrial usage like lubricants. Despite severe competition from the synthetic fiber industry in recent years, cotton is still holding its commercial value as an important natural fiber crop in the textile industry (Alkuddsi *et al.,* 2013). Cotton is primarily used in textile industries providing employment opportunity during production, processing, spinning, weaving and marketing throughout the world (Alkuddsi *et al*., 2013).

Cotton mainly possesses four species of the genus Gossypium (Malvaceae), namely *G. hirsutum* L., *G. barbadense* L., *G. arboretum* L., and *G. herbaceum* L. These were domesticated independently as source of textile fiber (Brubaker *et al*., 1999). Nowadays, *G. hirsutum* and *G. barbadense* are the major cultivated cotton species, with *G. hirsutum* accounting for 90% of world production (Jenkins, 2003). *G. barbadense* represents approximately 5% of world fiber production and is cultivated primarily in Egypt, Peru, Sudan, USA and parts of the former Soviet Union (Wu *et al.,* 2005). *G. arboreum* is mainly grown in India whereas *G. herbaceum* is grown in the drier regions of Africa and Asia (Jenkins, 2003).

In Ethiopia, Upland cotton is the only species grown by small and large scale producers. Cotton is a unique and important industrial crop and no other crop in Ethiopia can compete with cotton's potential for forward linkages with the industrial and service sectors (MOI, 2015). Ethiopia possesses three million hectares of land suitable for growing cotton on an area that equals the cotton land in Pakistan, the world's 4th largest producer. Although Ethiopia has a great potential for cotton production, it only uses 111, 886 hectares, which is 3% of the total land available for cotton and produces about 80,000 metric tons annually (MOI, 2015). The national average seed cotton yield in Ethiopia is low ranging from 2.0-3.0 ton/ha and 0.7-1.4 ton/ha for irrigated and rain fed conditions, respectively (Arkebe *et al*., 2014). The cause for low productivity and production of cotton in Ethiopia include insects pests especially white fly, aphids and the bollworm complex; lack of suitable varieties, poor management practices and poor marketing system.

Demand is rising because the annual spinning capacity of the industry increased from 25,000 to 111,000 tons of lint (ICAC, 2014). Currently, Ethiopia has about 14 textile factories and 50 medium-to-large garment manufacturers. There is a relatively better flow in the textile and garment sector; especially many Turkish textile firms are relocating to Ethiopia. Therefore, developing improved varieties is one of the measures to alleviate these constraints. In this regard, studying per se performance for the characters of interest is the primary precondition that breeders look into for the development of new varieties (Scossiroli *et al.,* 1963).

So far no studies on *per se* performance of different cotton traits contributing to yield parameters have been carried out in the Beneshangul-Gumuz Regional State in Ethiopia. Therefore, presence of adequate information on *per se* performance enables identification and release of promising cotton varieties. Thus, main objective of this study was to assess *per se* performances of experimental cotton varieties for seed cotton yield.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Assosa Agricultural Research Center's (AsARC) sub-testing site in Kamashi woreda (district) in Benishangul Gumuz Regional State in the western part of Ethiopia during the main cropping season of 2017/18. Kamashi woreda is one of main cotton cultivating areas in Benishangul-Gumuze. The Kamashi sub-center of AsARC is located 250 km east of Assosa town and 560 km west of Addis Ababa with an altitude of 1247 meter above sea level and found at 09° 31.172' N latitude, and at 035^{0} 35.488' E longitude. Kamashi woreda has a unimodal rainfall pattern, which starts at the end of April and extends to mid-November. The major soil type of Kamashi is Nitosol with a dark reddish brown color (AsARC Report, 2011). And also, its optimum temperature range is 28 to 32°C.

Experimental Materials and Design

In this study, a total of 14 genotypes including 12 elite genotypes and two check varieties were evaluated at Kamashi (Table 1). These genotypes were obtained from Werer Agricultural Research Center (WARC) which is a center of excellence for cotton research in the irrigated areas. The genotypes were organized in a randomized complete block design with three replications. Five rows of 5 m length were used for each plot. Inter-row and intra-row spacing of 90 cm and 20 cm, respectively, were used to make up plot sizes of 22.5 m^2 (5 rows x 5 m x 0.9 m) each. This translates to a population of about 55,000 plants on a per hectare basis.

Table 1. Twelve experimental cotton lines and 2 standard checks used in the study.

Entry number	Codes	Pedigree/Designation	Selection number
1	WARC-1	HTO#052 x Deltapine 90	21-7
2	WARC-2	Cucurova1518 x LG-450	35-4
3	WARC-3	Deltapine 90 x Cucurova1518	37-7
4	WARC-4	Deltapine 90 x Stam-59A	38-8
5	WARC-5	Del Cero x GL-7	8-2
6	WARC-6	ISA 205H x Stam-59A	11-4
7	WARC-7	ISA 205H x Beyazealtin/5	16-2
8	WARC-8	HS-46 x Stoneville 453	19-2
9	WARC-9	HS-46 x Stoneville 453	19-8
10	WARC-10	Stam-59 A x Cucurova 1518	30-2
11	WARC-11	Stam-59 A x Cucurova 1518	30-6
12	WARC-12	Stam-59A x Europa-5	-
13	(Check-1)	Deltapine 90 (na^{+})	-
14	(Check-2)	Stam-59A (na^{+})	-

na^{+}= Pedigree not available

Management Practices

All recommended agronomic practices which included land preparation to harvesting were followed as per the recommendations from research. Planting was carried out in early June with the onset of rains. Di-ammonium phosphate (DAP) and urea fertilizers were applied at the recommended rate, each at 100 kg per hectare. Whole DAP was applied at sowing while urea was applied in splits, 2/3 at sowing and 1/3 at initial flowering stage. To control grass and broad leaf weeds, two hand weeding were performed at critical stages of crop development. The first hand weeding was carried out 35 days after seedling emergence whereas the second weeding was performed 65 days after emergence or 30 days after the first weeding.

Performance measurement and statistical analyses:

Data were measured and recorded on days to 50% flowering, days to 65% boll opening, plant height, monopodia branches per plant, sympodial branches per plant, boll number per plant, boll weight, seed cotton yield, lint yield and lint percentage. All the data were subjected to analysis of variance (Fisher, 1958). Means for each trait were further separated and compared by using Duncan's multiple range (DMRT) test at 5% level of probability.

RESULTS AND DISCUSSION

The analysis of variance results for the ten traits studied are given in Tables 2. Highly significant ($P<0.01$) differences among genotypes were observed at Kamashi testing site for days to 50% flowering, days to 65% boll opening, plant height, number of monopodial branches per plant, number of sympodial or fruiting branches per plant, number of bolls per plant, for average boll weight, seed cotton yield, lint yield, and lint percentage or ginning outturn (GOT).

Table 2. Analysis of variance (mean square) for 10 traits of 14 experimental cotton varieties.

Traits	Replication	Genotypes	Error	CV
Days to 50% flowering	1.50ns	18.35**	1.60	1.42
Days to 65% boll opening	141.07*	111.53**	37.56	3.72
Plant height	2483.62**	1545.68**	291.53	12.79
Number of monopodial branches/plant	0.74ns	3.91**	0.45	7.66
Number of sympodial branches/plant	0.57ns	2.65**	0.32	6.60
Number of bolls per plant	1.87ns	6.48**	0.81	4.05
Boll weight in grams	0.21ns	0.22**	0.08	7.82
Seed cotton yield in kg per ha	235570.91ns	332418.31**	96973.04	14.11
Lint yield in kg per ha	45356.15ns	56175.97**	17464.58	14.45
Lint percentage or Ginning out turn	6.60**	7.93**	0.89	2.27

*, ** Indicate significance at the 0.05 and 0.01 levels, respectively; ns=non-significant;

Mean Performances of Experimental Cotton varieties

Range and mean values for 10 characters of 14 cotton genotypes evaluated at Kamashi testing site in 2017-18 cropping season are presented in Tables 3. Regarding phenological characters, days to 50% flowering ranged from 82.67 to 93.00 days while days to 65% boll opening ranged from 145 to 167 days. Shorter number of days to flower setting and boll opening indicated earliness of certain tested lines. The early flowering entry was the check Deltapinee-90 with 82.7 days from emergence followed by WARC-4 with 88.3 days. The late flowering lines were WARC-5 and WARC-1 with 93.0 and 92.7 days, respectively. The remaining entries were intermediate and ranged from 90.0 to 91.3 days. Deltapine-90 was also the early boll opener at 145 days and WARC-12 was the latest at 165.7 days after emergence (Table4). Ali and Khan (2003) have also reported that the number of days taken to flowering is considered as an important determinant of earliness. Iqbal and Jabbar, (2011) also found positive linkage between first flower formation and earliness. Hence, delay in flowering is a sign of late maturity which may be okay in non-moisture stress areas. Plant height ranged from 99.60 cm to 186.53 cm with the mean value of 133.48 and indicated a wide range of variability. Variations of genotypes for other traits are demonstrated in Table 3 and Table 4.

Yield and Yield Components of Experimental Cotton Varieties

Seed cotton yield (SCY) ranged from 1601.20 to 2724.70 kg/ha with a mean value of 2207.20 kg/ha. The top yielders, as shown in Table 4, included WARC-4, WARC-8, WARC-3, WARC-9, WARC-11 and the check Deltapine-90 with 2724.9, 2583.7, 2564.9, 2433.1, 2353.1 and 2413.3 kg/ha, respectively. These entries with the exception of WARC-3 have satisfactory levels of lint percentages and could serve as good source for cotton variety improvement. Lint is a major and most important component of cotton production, and a vital raw material for the textile industry.

Boll number per plant (BNP) and boll weight (BWt) are important yield components that contributed to increased seed cotton (Table 4). Entries with higher boll number than the trial mean (3.62 g) included WARC-2, WARC-5, WARC-6, WARC-10 and the two checks Deltapine-90 and Stam-59A. These test entries also had ball weights larger than the mean with the exception of WARC-6 and Stam-59A (Table4). Larger number of bolls indicated the capacity of certain entries to retain more productive bolls under stress or otherwise.

Table 3. Minimum and maximum values, mean and standard error of mean (SE) for the 10 traits of 14 experimental cotton varieties evaluated at Kamashi testing site.

Traits	Min. Value	Genotypes with Min. value	Max. value	Genotype with Max. value	Mean	SE	CV (%)
Days to 50% flowering	82.70	Deltapine-90	93.00	WARC-5	90.29	0.73	1.42
Days to 65% boll opening	145.00	Deltapine-90	167.33	Stam-59A	159.29	3.51	3.72
Plant height	99.60	Deltapine-90	186.53	Stam-59A	133.50	9.86	12.79
Number of monopodial branches per plant	6.21	WARC-2	10.22	WARC-3	8.76	0.39	7.66
Number of sympodial branches per plant	7.46	WARC-11	10.98	WARC-6	8.89	0.33	6.33
Number of bolls per plant	20.00	WARC-7	24.69	Deltapine-90	22.17	0.52	4.05
Boll weight, grams	2.95	Stam-59A	3.95	WARC-10	3.62	0.16	7.82
Seed cotton yield, kg/ha	1601.00	WARC-1	2725.00	WARC-4	2207.20	180	14.11
Lint yield, kg per ha	645.00	WARC-1	1140.00	WARC-4	914.45	76.3	14.45
Lint percentage or GOT	37.60	WARC-3	43.62	WARC-10	41.46	0.54	2.27

Table 4. Performance of 14 experimental cotton varieties tested at Kamashi in 2017.

Cotton Genotypes	Mean morphological and agronomic values									
	D50F	D65BO	PHt	NMoB	NSyB	NBP	BWt	SCY	LY	L%
WARC-1	92.7ba	158.0bdac	103.6d	7.1ef	8.8ced	21.6dce	3.75dac	1601.2e	644.6d	40.26ed
WARC-2	90.7bc	161.3bdac	120.7cd	6.2fa	9.8b	24.2a	3.52dac	2202.2bc	917.4ba	41.66bdc
WARC-3	90.7bc	167.0a	142.3cb	10.2a	8.0fg	21.2dce	3.93ba	2564.9ba	965.4ba	37.64f
WARC-4	88.3d	156.7bdc	116.5cd	7.8ecd	9.0ebd	21.1dce	3.84bac	2724.9a	1139.5a	41.82bdc
WARC-5	93.0a	152.3de	119.1cd	7.7ed	8.8ebd	22.2bc	3.59dac	2017.5edc	856.9bcd	42.47bac
WARC-6	90.0dc	159.3bdac	144.3cb	9.6ba	11.0a	24.0a	3.33de	1668.1ed	686.0cd	41.13edc
WARC-7	91.0bac	160.7bdac	135.8cb	8.9bc	8.4egd	20.1e	3.61bdac	1958.5edc	844.4bcd	43.12ba
WARC-8	90.7b	154.7dec	134.5cb	8.6bcd	7.7g	20.7de	3.87bac	2583.7ba	1049.0ba	40.60ed
WARC-9	91.3bac	156.7bdc	155.0ba	9.5ba	8.9ebd	22.0dc	3.71dac	2433.1bac	1056.4ba	43.42a
WARC-10	90.0dc	162.3bdac	120.9ba	9.5ba	9.7cb	22.3bc	3.95a	2160.0bdc	942.2ba	43.62a
WARC-11	91.0bac	163.0bac	137.7cb	8.9bc	7.5g	20.4e	3.44dc	2353.1bac	1004.1ba	42.67bac
WARC-12	90.3dc	165.7dcdc	152.1b	9.5ba	8.2feg	22.0dc	3.74dac	2184.7bdc	869.5bc	39.80e
Deltapine-90	82.7e	145.0e	99.6d	9.7ba	9.7cb	24.7a	3.47bdc	2413.3bac	976.2ba	40.45ed
Stam-59A	91.7bac	167.3a	186.5a	9.4ba	9.3cbd	23.7ba	2.95e	2035.3edc	850.7bcd	41.80bdc
Trial mean	90.3	159.3	133.5	8.76	8.9	22.16	3.62	2207.20	914.44	41.46
CV (%)	1.42	3.85	12.79	7.66	6.33	4.05	7.82	14.11	14.45	2.27
$LSD_{(0.05)}$	2.16	10.29	28.66	1.13	0.95	1.51	0.48	522.60	221.8	14.45

* Within columns, values having a letter in common are not significantly different at the 5% significance level. D50F=Days to 50% flowering; D65BO=Days to 65% boll opening; PHt=Plant height; NMoB= Number of monopodial branches per plant; NSyB=Number of sympodial branches per plant; NBP=Number of bolls per plant; BWt=Boll weight in grams; SCY=Seed cotton yield in kg per ha; LY=Lint yield in kg per ha; L%=Lint percentage or GOT (Ginning out turn).

CONCLUSIONS

In this study, the analysis of variance showed significant differences among the tested experimental varieties for all phenological and agronomic traits. This indicated the existence of variability among the tested lines and for a chance to improve seed cotton yield and other desirable characters through adaptation testing and selection.

Ethiopia has great potential for cotton production both in the irrigated and rain-fed areas. But, demands for cotton lint by the textile industries have not been satisfied for a long time. Benshangul-Gumuz Regional State in western Ethiopia is one of the potential areas for cotton production. Testing of advanced cotton lines in this region has indicated the presence of climatic suitability and adaptability of potential cotton lines. Based on seed cotton yield performance at Kamashi Research Sub-Center of Assosa Agricultural Research Center, WARC-3, WARC-4, WARC-8, WARC-9 and WARC-11 can be further evaluated in more number of locations in the region and considered for release and production by farmers. Also, advanced lines with high lint percentages (≥ 43%) can be used in cotton breeding programs to enhance lint yields.

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