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Adaptation Verification of Irrigated Cotton Cultivars for High Productivity and Economic Advantage for Large Scale Production at Tendaho Sugar Estate, Ethiopia

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Abstract: Adaptation performance field experiment on irrigated cotton cultivars for high productivity for large scale production and economic advantage were conducted in RCB Design by replicating four times to identify the high yielding with high quality cotton cultivar using surface irrigation at Tendaho sugar estate. All collected data were analyzed using GenStat 17th Edition software and mean comparisons among treatment means were made by LSD (5%). Cotton quality comparisons were also done based on the national quality measurement standards and the cotton quality laboratory analysis was done in Cotton Central accredited laboratory of Ethiopia under Ethiopian Textile Development and Research Institute. Significant difference ($p<0.05$) among the tested cotton cultivars were reported for stand count (SC), number of unopened balls per plant and percent of 65 percent opened ball. However, there were no significant variability for total cotton yield (Y (kg/ha), lint yield and moisture adjusted yield (MoiAd_Y_Qt_Ha) at ($p<0.05$) significance level. From the candidate cultivars, woyito and worer shown first and second high cotton productivity with 32 and 31.1 qt/ha cotton yield respectively followed by Stam-9-A as third with 30 qt/ha. In the other case, Stam-9-A and Delta ranked first for the major cotton quality standard measures. From this, it can be concluded that candidate genotype Stam-9-A which is third in productivity and first in cotton quality could have better advantage for the Estate. Therefore, based on the current adaptation trail result candidate cultivar Stam-9-A is recommended for commercial production in the study farm area.

Keywords: Adaptation, Cotton, Cultivar, Quality, Yield

1. Introduction

Agriculture is the 'engine for growth' in Africa with its immense land area covering 3 billion ha has 1.3 billion ha of agricultural land out of which only 252 million ha (19.36%) is arable [1]. With subsistence agriculture practiced by majority small holder farmers, yield gaps are high and poor soils, amongst other constraints add to the difficulties for sustainable farming and incomes. Average real per capital income in 2010 was $688 (in constant 2000 US$) compared to $1717 in the rest of the developing world [2]. Sub-Saharan Africa has experienced encouraging economic growth averaging about 4.5 per cent with some non-oil-exporting countries reaching an average of more than eight per cent [3]. Despite this impressive economic performance, agricultural transformation has been slow and growth rather sluggish.

Ethiopia as part of the region relies much on agriculture, although considerable and dynamic efforts made towards increasing agricultural production; the country has yet to go a long way to secure self-sufficiency in strategic food crops consequently, the country is obliged to import large quantities of wheat and other grains. Even though much of the irrigable lands are not yet used for various reasons and numerous reports indicated Ethiopia has excellent agro ecology as a

result have good agricultural potential that would allow to produce surplus agricultural products but yet the country dependent merely on rain-fed agriculture through harnessing its fertile and irrigable land in the lowland areas.

Cotton is more important than the various synthetic fibers, and it is grown all over the world in about 80 countries [4]. Currently, it is an important cash crop especially for a number of developing countries at local and national levels [5]. Ethiopia is one of the African countries that produce and export cotton [6]. The country is also believed to be one of the origins of cotton and its cultivation as it has a unique history in the country's agriculture because there are indigenous diploid (2n = 26) cultivated and wild species of cotton [7]. The indigenous cultivated species include G. arboreum and G. herbaceum. The distribution of the wild species of the B genome (G. anomalum subsp. se-marense) and those of the E genome (G. somalense, G. bricchettii and G. benadirense) have been documented. Ethiopia's major potential cotton growing areas include Omo-Ghibe, WabiShebele, Awash, Baro-Akobo, Blue Nile, and Tekeze river basins [8].

The basic conditions required for the effective production of cotton include a long frost-free period, a temperature range of 18–32°C and 600–1200 mm of water over the growing cycle, which typically lasts 125–175 days [9]. Therefore, Ethiopia has a very good cotton-growing condition and a large amount of land potentially suitable for cotton production [8]. The country possesses 2,697,640 hectares of land suitable for growing cotton; an area that equals the cotton land in Pakistan which is the world's fourth largest producer, but recently cultivated only 3% of this area for cotton production [10]. As a result, the amount of cotton produced in the country is small and the current domestic cotton production is much lower than the potential [11].

Ethiopia's dream is to become a middle income economy by 2025 by realizing an average annual economic growth of 10% through building a modern and productive agricultural sector, strengthening the industrial base and growing exports. Ethiopia's cotton production, which has remained fairly flat in recent years, was estimated at 40,000 metric tons 2014/15 and expands slightly in 2015/16 to 43,500 metric tons. Meantime, consumption is forecast to outstrip domestic cotton production in large part due to the demands of the rapidly-expanding textile/apparel industry. Thus, it is anticipated that imports, will fill this gap. Imports are estimated at 8,000 metric tons in 2014/15 and 12,000 metric tons in 2015/16 [12].

Currently the Government of Ethiopia has started several development projects in every sector of the economy. As a part of this effort since 2010 onwards the Ethiopia Sugar Corporation is working to move the nation reach among the top ten sugar producing countries of the world by 2025 (GTP2), hence the corporation is developing irrigation infrastructures for about 420, 000 ha of land in Omo, Awash, Beless and Tekeze rivers basins (GTP-1) by establishing ten new sugar factories in different parts of the country. Among the newly established sugar estates, Tendaho has about 50,000ha farm land size. However, due to several reasons much of the irrigable land was not yet cultivated by sugarcane.

The global practices indicate that most of the sugar producing countries such as India, Thailand, Australia, South Africa and Brazil are running their sugar industries with complementary crops and livestock's enterprises. Therefore, Ethiopian Sugar Corporation is utilizing all efforts on harmonizing crop development with sugarcane and established a wing tasked with crop, horticulture and livestock production to enhance product diversification [13].

Even if EIAR has a role to coordinate national cotton research program in the country [14], most of the proposed large fertile irrigable low land areas are owned by sugar estates so that they have not been addressed by the national agricultural research systems in developing improved crop varieties yet. Therefore, it seems essential to undertake a specific variety adaptation trial at each location and generate scientific information on Ecological Suitability, specific Adaptability and economic Profitability of producing irrigated cotton at Tendaho Sugar Factory. Therefore, the objective of this verification trial was to evaluate Ecological Suitability, Adaptation and Profitability of irrigated cotton thereby, to identify high yielding cotton varieties better adapted to Tendaho sugar estate.

2. Material and Methods

2.1. Description of the Study Area

Tendaho Sugarcane Estate is found in Afar Regional State of Ethiopia located at 41°3'E longitude and 11°50' N latitude, 374 m above sea level elevation, receiving annual rainfall of about 200 mm with mean minimum and maximum temperature of 16.8°C and 38.8°C, respectively.

Table 1. *Monthly Mean Maximum, Mean Minimum and Mean Average Temperature of Tendaho Sugarcane Estate (January, 1963 – December, 2018).*

Temperature (°C)	JAN	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Mean Maximum	33.0	35.9	38.4	39.9	40.9	41.8	42.8	41.5	39.8	40.2	37.1	34.8	38.8
Mean Minimum	12.4	13.9	15.0	17.1	18.3	20.1	20.5	20.3	20.1	16.6	13.9	13.0	16.8
Mean Average	22.7	24.9	26.7	28.5	29.6	30.9	31.6	30.9	30.0	28.4	25.5	23.9	27.8

2.2. Methods and Materials Used in the Experiment

Five candidate Cotton genotypes; Delta, Inosa, Werer, Weyto and Stam -9-A developed in Worer Agricultural Center and recommended to agro ecologies of lower awash valley and similar warm climates low altitude, were used for the trial at Tendaho Sugar Estate Dubti section. The seed source was Ethiopian Institute of Agricultural Research Worer Research center.

The candidate Cotton cultivars were evaluated in RCBD

with four replications using furrow irrigation at Tendaho Sugar Estate, Dubti site. The plot size of the trial was 10 m by 10 m (100 m^2). The trial was carried out using furrow irrigation during June 2018 to end of October 2018 following recommended agronomic practices. Data were collected for major agronomic growth parameters, yield and yield components, cotton quality parameters and standard quality measurements parameters were collected based on ETDRI procedures.

2.3. Analysis of Variance

The data of different traits were collected and statistically analyzed using GenStat 17th Edition Software. Analysis of Variance for RCBD was computed. Mean comparisons among treatment means were also analyzed by LSD methods at 5% significance level.

The RCBD design analysis of variance was used to derive variance components as structured and stated by Cochran and Cox [15].

RCBD ANOVA was computed using the following model:

$$Yij = \mu + rj + gi + \varepsilon ij$$

Where, Yij = the response of trait Y in the i^{th} genotype and the j^{th} replication

μ = the grand mean of trait Y

rj = the effect of the jth replication

gi = the effect of the ith genotype

εij = experimental error effect

2.4. Profitability Analysis

2.4.1. Sources of Data

In this study primary and secondary sources of data were used. Cotton cultivars of farm production data were used as primary data and published and unpublished sources of data were used as secondary data source.

2.4.2. Data Analysis

In this study descriptive statistics were implemented as a tool for data analysis.

Table 2. *Cotton Quality Standard.*

No	Descriptor	Grade A	Grade B	Grade C
1	Moisture%	<8%	<8%	<8%
2	Micronier value*	3.5 _ 4.2	4.3 _ 4.9	3.2 _ 3.4 and 5 _ 5.2
3	Maturity	> 85%	81_ 84%	75 _ 80%
4	UHML (mm)*	28.5mm and above	27mm _ 28.4mm	25mm_26.9mm
5	UI%*	> 83%	81 _ 82%	76 _ 80%
6	SF%	<10%	11 _ 20%	21 _ 32
7	Strength (g/tex)*	>29GPT	26 _ 28.9GPT	25 _25.9GPT
8	Color grade	11 _ 1 to 21_ 4	31_1 to 31_4	41_1 to 51_4
9	Trash content (%)	< 3.5	3.5 _ 4.5%	4.6 _ 5%
10	Average number of sticky points	0 _ 10	11 _ 20	21 _ 32

Source: Ethiopian Textile Research and Development Institute Grading /ETRDIQG/

3. Result and Discussion

3.1. Variance

As indicated in Table 3, there were significant variation ($P<0.05$) among the treatments for stand count (SC), number of unopened balls per plant and percent of 65 percent opened ball. Stand count (SC) is one of the major characters of cotton that determine yield potential and has direct and significant relationship with number of effective balls per plant and total plot yield.

Table 3. *NOVA, LSD and CV.*

Source of variation	d. f.	s. s.	m. s.	v. r.	F pr.	l. s. d.	cv%
Stand ct	4	231.2	57.8	5.3	0.011*	5.086	7.8
Residual	12	130.8	10.9				
PH	4	1665.9	416.5	2.81	0.074	18.74	14.7
Residual	12	1776.4	148				
Peaking_date_First	4	25.7	6.425	2.69	0.083	2.383	1.3
Residual	12	28.7	2.392				
No_Un_Oped	4	61.648	15.412	3.75	0.033*	3.123	35
Residual	12	49.308	4.109				
No_Open_Ball	4	12.24	3.06	0.28	0.885	5.085	24.6
Residual	12	130.73	10.89				
Initial_Squaring	4	8.7	2.175	1.05	0.423	2.219	4.9
Residual	12	24.9	2.075				
Initial_Flowering	4	5.3	1.325	1.67	0.22	1.371	2.2

Source of variation	d. f.	s. s.	m. s.	v. r.	F pr.	l. s. d.	cv%
Residual	12	9.5	0.7917				
Initial_Boll_opening	4	77.3	19.325	2.56	0.093	4.236	3.1
Residual	12	90.7	7.558				
First_picking_kg	4	275.61	68.9	2.3	0.118	8.43	22.2
Residual	12	359.38	29.95				
Emergence	4	2.7	0.675	0.42	0.791	1.954	20.1
Residual	12	19.3	1.608				
Average_boll_wt_gram	4	1.5778	0.3944	1.97	0.163	0.689	7.7
Residual	12	2.403	0.2002				
%65%_Boll_opening	4	253.7	63.425	6.54	0.005*	4.796	2.9
Residual	12	116.3	9.692				
%50%_Flowering	4	2.3	0.575	0.26	0.898	2.289	2.8
Residual	12	26.5	2.208				
%30bolls_weight_kg	4	0.00147	0.000368	3.13	0.056	0.0167	6.2
Residual	12	0.00141	0.000118				
%30_bolls_weight_gram	4	1408.5	352.1	1.95	0.166	20.69	7.7
Residual	12	2165	180.4				

3.2. Yield Comparison

As shown in the result, there was variability among the studied candidate genotypes for the rest twelve agronomic traits even though there were statistically not significant. There were no significant variability for total cotton yield (Y (kg/ha), lint yield and moisture adjusted yield (MoiAd_Y_Qt_Ha) (table 4). There was no significant variability among tested cultivars for cotton yield as indicated in table (4 and 5) in variance analysis and mean comparison.

Table 4. *ANOVA for Cotton Yield in kg/ha, qt/ha and moisture adjusted yield qt/ha.*

	Source of variation	d. f.	s. s.	m. s.	v. r.	F pr.
	Rep stratum	3	2382217	794072	1.78	
	Rep.*Units* stratum					
Y (kg/ha)	Tret	4	4098963	1024741	2.3	0.118
	Residual	12	5344695	445391		
	Total	19	11825876			
	Source of variation	d. f.	s. s.	m. s.	v. r.	F pr.
	Rep stratum	3	238.22	79.41	1.78	
FY (qt/Ha)	Rep.*Units* stratum					
	Tret	4	409.9	102.47	2.3	0.118
	Residual	12	534.47	44.54		
	Total	19	1182.59			
	Source of variation	d. f.	s. s.	m. s.	v. r.	F pr.
	Rep stratum	3	201.63	67.21	1.78	
MoiAd_Y_Qt_Ha	Rep.*Units* stratum					
	Tret	4	346.94	86.73	2.3	0.118
	Residual	12	452.38	37.7		
	Total	19	1000.94			

Table 5. *Cotton Yield mean comparison.*

Treatments	Y (kg/ha)		Tret	FY (qt/Ha)		Tret	MoiAd_Y_Qt_Ha	
weyto	3474	a	Weyto	34.74	a	weyto	31.96	a
werer	3383	a	Werer	33.83	a	werer	31.12	a
Stam -9-A	3261	a	Stam -9-A	32.61	a	Stam -9-A	30	a
Inosa	2507	a	Inosa	25.07	a	Inosa	23.06	a
delta	2415	a	Delta	24.15	a	delta	22.22	a

Even though there was no significant variability among studied cultivars for cotton yield, but there was high variation in magnitude for cotton yield productivity (table 6). Hence, candidate cultivar Woyto recorded the first higher adjusted

cotton yield (32 Qt/ha), followed by Werer (31.1 Qt/ha) second and Stam-9-A (30 Qt/ha) as a third.

Table 6. *Mean, Grand mean, l. s. d. and CV for cotton yield.*

	delta	Inosa	werer	weyto	Stam -9-A	Grand	l. s. d.	CV
Y (kg/ha)	2415	2507	3383	3474	3261	3008	1028.2	22.2
FY (qt/Ha)	24.2	25.1	33.8	34.7	32.6	30.08	10.28	22.2
MoiAd_Y_Qt_Ha	22.2	23.1	31.1	32	30	27.68	9.46	22.2

3.3. Cotton Quality

As indicated in the material and method section, cotton quality comparison were done based on the national quality measurement standard of the country and the cotton quality laboratory analysis was done in Cotton Central accredited laboratory of Ethiopia under Ethiopian Textile Development and Research Institute.

The quality analysis were done for Moisture%, Micronier value, Maturity, UHML (mm), UI%, SF%, Strength (g/tex), Color grade, Trash content (%) and Average number of sticky points. As indicated in table 7, candidate cultivars quality grade to Moisture% recorded small variation within the range of the standard for example werer, weyto and Stam -9-A scored grade A for 6.85%, 6.28% and 6.73% respective value of moisture measurement.

Similarly, candidate cultivars did not show significant variation for Micronier value and all candidate cultivars scored grade C quality with indicated values in table 7. All of the candidate cultivars scored quality grade A for a parameter Maturity; while Delta and Stam-9-A scored quality grade A for UHML (mm) parameter whereas Inosa, worer and Woyito scored B as indicated in table 7. Except woyito (B) all candidate cultivars scored quality grade A for UI%* parameter.

All candidate cultivars scored quality A for SF% and Color grade parameters as shown in table 7. Four candidate cultivars scored quality grade B for Strength (g/tex) quality parameter but Stam-9-A scored A. while, delta, Inosa, werer and weyto scored B for Trash Content (%) but Stam -9-A scored lower quality grade C. Similarly as indicated in (table 7) candidate cultivar delta scored A for Av No sticky points, grade score B for Inosa and Stam-9-A while C for werer as indicated.

Table 7. *Cotton quality ETRDI Laboratory Result Report.*

Treatments	Moisture%	Micronier value*	Maturity	UHML (mm)	UI%*
delta	6.83	5.64	0.88	28.58	83.8
ETRDI QG	A	C	A	A	A
Inosa	6.73	5.85	0.88	27.57	83.2
ETRDI QG	A	C	A	B	A
werer	6.85	5.32	0.87	28.26	83.9
ETRDI QG	A	C	A	B	A
weyto	6.28	5.24	0.87	27.09	82.6
ETRDI QG	A	C	A	B	B
Stam -9-A	6.73	5.22	0.88	30.07	84.6
ETRDI QG	A	C	A	A	A
Treatments	SF%	Strength (g/tex)	Color grade	Trash Content (%)	Av No sticky points
delta	8.23	26.08	11-1	0.375	7.5
ETRDI QG	A	B	A	B	A
Inosa	8.45	27.38	11-2	0.375	14
ETRDI QG	A	B	A	B	B
werer	8.33	26.23	11-1	0.426	21.25
ETRDI QG	A	B	A	B	C
weyto	8.9	26.65	11-1	0.358	14.75
ETRDI QG	A	B	A	B	B
Stam -9-A	7.3	29.6	11-2	0.492	16
ETRDI QG	A	A	A	C	B

Quality Summery

Table 8. *Cotton quality test comparison summery.*

Treatments	Quality Rank
Stam -9-A	1st
delta	1st
Inosa	3nd
werer	3nd
weyto	5th

As shown in the table 8 Delta and Stam-9-A ranked first for the major cotton quality standard measures. But woyito and worer shown first and second high cotton productivity with 32 and 31.1 qt cotton yield quintal per hectare respectively followed third by Stam-9-A 30 qt/ha.

4. Conclusion and Recommendation

Cultivars Woyito and Worer scored first and second high cotton yield as compared to the others with 32 and 31.1 qt/ha respectively followed by Stam -90A with 30 qt/ha ranked third. As indicated there with respect of cotton quality comparison, stam-9-A and Delta scored first in quality parameters. The result and discussion indicated cultivars variance analysis shown non-significant variability for Yield and related parameters and cotton grade quality is a major determinant factor for produce market. Therefore, we can conclude that candidate genotype Stam-9-A which is third in productivity and first in cotton quality could have better advantage for the Estate. Hence, based on the current adaptation trail result candidate Stam-9-A is recommended for commercial production in Tendaho Dubti farm area.

Appendix

Mean Comparison.

Table A1. *Mean LSD Multiple range test.*

Treatments	Stand ct	comp	PH	comp	1st Peaking_date	comp	No_Un_Open	comp	No_Open Ball	comp
delta	38.75	b	88.82	a	122.2	a	9.05	a	12.88	a
Inosa	44	a	93	a	121.8	ab	5.65	b	13.62	a
werer	37.75	b	67.17	b	120	ab	5.75	b	14.82	a
weyto	46.25	a	78.4	ab	119.2	b	4.15	b	12.65	a
Stam -9-A	44.75	a	86.32	ab	121.5	ab	4.35	b	13.03	a

Treatments	Initial_Squaring	comp	Initial_ Flowering	comp	Initial_Bo opening	comp	First Picking /kg	comp	Emergence	comp
delta	29.5	a	41.5	ab	88	ab	19.81	a	6.5	a
Inosa	29.5	a	42.25	a	91.75	a	20.56	a	5.75	a
werer	31	a	41	ab	88.25	ab	27.74	a	6	a
weyto	29.25	a	41.25	ab	85.75	b	28.49	a	6.5	a
Stam -9-A	29.25	a	40.75	b	89.5	ab	26.74	a	6.75	a

Treatments	Average bo wt/gm	comp	%65%_Boll opening	comp	%50%_Flowering	comp	%30bolls Weight/kg	comp	%30_bolls Weight/gram	comp
delta	5.315	ac	111.5	a	53	a	0.16	b	159.5	ac
Inosa	5.912	abc	112	a	52.25	a	0.1775	a	177.3	abc
werer	6.062	a	107.2	ab	52	a	0.1825	a	181.8	ab
weyto	5.697	abc	102.5	b	52.25	a	0.17	ab	170.9	abc
Stam -9-A	6.06	ab	110.8	a	52.25	a	0.1825	a	181.8	a

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