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EVALUATION OF FINENESS AND MATURITY IN EGYPTIAN COTTON GRADES USING TFT INSTRUMENT

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ABSTRACT

The four commercial Egyptian cotton varieties (Gossypium barbadense L); Extra-G 92, Extra-G 96, Super-G 97, and Giza 98 that collected from Egyptian gin mills through 2025 season. Within each cotton variety three grades, namely; Fully Good (FG), Good (G), and Fully Good Fair (FGF). All studied samples were tested in Cotton Grading Department, Cotton Research Institute (CRI), Agricultural Research Center (ARC), Giza, Egypt. Three different instruments concluded: Fiber Classifying System (FCS); module called Wira, Tomsic Fiber Tester (TFT), and MicroLab. Both of Wira and TFT measure fineness, maturity and micronaire value. MicroLab measure's structure attributes; diameter and perimeter. The relation among the data of the three instruments was found to be quite accuracy for micronaire and maturity ratio. Both of Wira and TFT are better for speedy fiber classification whether for research or commercial. Meanwhile; in MicroLab both of diameter, perimeter and maturity as well wall thickness may be able to be the real orientation for breeder to improve cotton varieties and manufactures proper selections. Correlation coefficient with Receiver Operating Characteristics curve (ROC) curve proved that TFT with FCS were superior discriminative ability compared to TFT with MicroLab methods by assessing the performance of classification models and select an optimal point by percentages of Area Under Curve (AUC) for both of micronaire and maturity ratio; 0.998 and 0.888, 0.830 and 0.811 and finally 0.758 and 0.650 for FCS, TFT and MicroLab, respectively.

Keyword: Egyptian cotton grades, Fineness and Maturity, FCS, TFT, MicroLab and Roc curve.

1 INTRODUCTION

Cotton is one of the most important natural fibers used in spinning and weaving, as a large sector of global industries depends on it, which require high-quality raw materials with uniformity and consistent properties which has intrinsic and extrinsic relations. Moreover, cotton fiber remains a strategically important natural resource, linking agriculture, scientific research, and industrial development, while continuing to evolve through technological advancements in testing and processing performance. Egyptian cotton represents one of the finest natural textile fibers worldwide, distinguished by its high tensile strength which improve yarn durability, superior fineness and maturity that allows production of fine and smooth yarns, High elongation and elasticity enhance fabric comfort improves spinning efficiency (Mona Shalaby *et al*. (2021), Mona shalaby and Younis (2025), and Liu *et al*. (2026)).

Among the basic properties that determine the quality of cotton with different multi-environments and its suitability for industrial use are the properties of length, fineness, maturity, elongation, strength and trash content as reported by Liu *et al*. (2001), Frydrych and Thibodeaux (2010), Greveniotis *et al*. (2017), Gundim *et al*. (2020), Zeidman and Sawhney (2022), Yang *et al*. (2023), and Qiu *et al*. (2025).

Fiber fineness and maturity are vital important factor in yarn mills to let the yarn manufacture be in the right trend with target fiber attributes. Using several instruments to get fineness and maturity characteristic give huge keep up with the used one.

Either fineness or maturity are key direct influences on fiber performance during the various spinning stages and on the quality of yarns and fabrics. Where; fineness affecting strength, evenness, spinning value of cotton. Meanwhile; maturity determines processing performance of yarn and fabrics.

On one hand; the structural properties of cotton fineness are shown as fiber's diameter or mass per unit length, perimeter, diameter and cross-sectional area. Fineness is typically expressed in millitex (mTex) which represents micrograms per meter of fiber length as illustrated by Yongliang *et al*. (2014) and Yongliang *et al*. (2015). The fiber perimeter and diameter of Egyptian cotton varied by variety. Perimeter is a measure of the biological fineness and each variety typically produces fiber with a characteristic perimeter. Fine fibers are generally desirable for producing high quality yarns and fabrics but low micronaire value may refer to maturity not fineness, so it is a must to be aware of parameters of each property.

On the other hand; maturity is the area of the cell wall relative to the area of a circle having the same perimeter as elucidated by Ramey (1982) that maturity is the degree to which the cotton fiber's secondary cell wall has developed and thickened. A ratio closer to 1 indicates a more developed and mature fiber as shown by Paudel *et al*. (2013) and Wang *et al*. (2019). Mature fibers are stronger and more uniform; leading to better processing and a higher quality final product. Immature fibers can cause problems such as poor dye uptake and weakness in the yarn as detected by Liu and Delhom (2023) and Liu and Chang (2024).

Micronaire is a widely used measurement that provides an estimate of both the fineness and maturity of cotton fibers. Therefore, assessing both fineness and maturity separately using several instruments are necessary to continue conducting applied studies that link cotton fiber properties with performance results obtained in order to support and develop the cotton industry and enhance its efficiency.

The evaluation of cotton grading fiber properties is essential for classification, quality control, breeding programs, and industrial optimization. Using modern testing systems, such as High and medium Volume Instruments (HVI) and (MVI) for advanced laboratories to enable accurate measurement of fiber characteristics, supporting decision-making in cotton production, marketing, and textile manufacturing (Mona Shalaby *et al*. (2021) and Mona Shalaby (2024)). There are several instruments such as:

- Digital microscope such as MicroLab which is the method which deals with the cross section of cotton fibers constitutes with an excellence reference method of maturity and fineness measurements with detailed explanation by Brims and Hwang (2010) to provides a more complete understanding of the fiber's quality and processing characteristics (Liu *et al*. (2023)).
- High volume Tester instruments such as TFT is used for rapid and standardized evaluation of cotton fiber properties in commercial classification and industrial applications due to its high testing capacity and repeatability.
- Medium volume instruments such as FCS give opportunity to semi-automated, moderate sample capacity, used in national cotton classing centers which focus on classification a quality grading support.

Different instruments such as FCS, TFT and MicroLab of testing cotton for fineness and maturity was reviewed to give reliable, accurate and efficient ways of measuring due to the importance to textile performance. Then using any type of available instruments whether high (TFT) or medium (FCS) volume instruments are practically applied in terms of less time and speedy operations compared to MicroLab practically which it is too slow to be applied.

High-volume instruments are optimized for speed and large sample batches. In spite of; FCS offers slightly slower but more adjustable modular testing. Both cover the standard set of cotton fiber properties, but FCS emphasizes modular data collection which can be more detailed per parameter-whereas high-volume systems give all parameters quickly in one pass. The results demonstrated strong agreement between the High-Volume Instrument (TFT) and the Fiber Classifying System (FCS) for fundamental fiber properties such as length, strength and micronaire. However, slight variations in elongation and distribution parameters were observed due to differences in testing mechanics and fiber sampling principles.

Both types are accurate; HVI and TFT are excellent for standardized trade values, and FCS can offer very consistent lab-level data, with subtle differences in certain metrics. All in all; TFT is very well standardized globally for commercial classification, strong calibration to international cotton standards, the throughout yields results that are consistency matter with widely recognized in trade, measurements are highly reproducible across labs with consistent calibration which responsible sectors need rapid classification for commercial or trading purposes with data that aligns with international cotton testing standards

Therefore, the integration of results obtained from instruments measurements allows statistical analyses for a more comprehensive evaluation of cotton fiber quality, improving the accuracy of measurements, assessing the feeble points of measurements, supporting better decision-making in cotton breeding for quality assessment, and industrial processing as seen by Fawcet (2006) and Mona Shalaby (2023).

It is importance to characterize both of fineness properties and maturity measurements of Egyptian cotton grades using TFT, FCS, and MicroLab instruments and assessing the efficiency of them.

2 MATERIALS AND METHODS

This present study concluded four Egyptian cotton varieties (Gossypium barbadense L). This commercial varieties namely; Giza 92 (Extra- G 92; belonging to Extra-strength), Giza 96 (Extra- G 96; belonging to Extra-length), Giza 97 (Super- G 97) (belonging to long staple-Delta) and Giza 98 (G 98) (belonging to long staple-upper Egypt). These varieties were collected from gin mills around the country through 2025 season. Cotton fiber samples of the three studied grades were Fully Good (FG), Good (G), and Fully Good Fair (FGF).

All studied samples were tested in Cotton Grading Department, Egyptian & International Cotton Classification Center (EICCC), Cotton Research Institute (CRI), Agricultural Research Center (ARC), Giza, Egypt. Using three different instruments concluded:

Fiber Classifying System (FCS) which stands for medium volume instrument. FCS has several modules for cotton lint properties. Herein the used module was Wira for measuring Micronaire, Maturity Ratio, Maturity percent and Linear Density.

Tomsic Fiber Tester (TFT) which stands for high volume instrument and has several modules for cotton lint properties, is used to measure Micronaire and Maturity Ratio.

Both of FCS and TFT are in compliance with ASTM D8394-21

MicroLab performed on each cross section are: use a graphic digitizer to trace the outline of cross sections viewed under microscope. The data processed by a computer program is used to calculate cross sectional area, perimeter and diameter then calculate micronaire and maturity ratio. The video analyser is in compliance with ASTM D1442 (Rodgers *et al*. (2012), Rodgers *et al*. (2013) and Video analyzer (2024)).

All cotton samples were conditioned at a constant relative humidity of 65 ± 2% and a temperature of 21 ± 2^{o} by using non-condensing; UnflairTM (2023) equipment (Air Technology System).

Using the Receiver Operating Characteristic (ROC) curve herein is to evaluate the diagnostic performance of CCS, TFT and MicroLab instruments by examining the relationship between sensitivity and 1–specificity across different varieties and grades. Sensitivity and specificity measure the accuracy of a diagnostic test or classifier. X-axis: 1 – specificity, Y-axis: sensitivity, diagonal line which is the reference line representing random classification (AUC = 0.5), upper-left curve: Perfect classification model (AUC = 1, curve reaches the top-left corner) and lower curve: worst classification model (AUC = 0, curve below the diagonal) which sensitivity represents the ability of the model to correctly identify true cases, whereas specificity reflects the ability to correctly identify the false cases.

Hanley and McNeil (1982), Fawcett (2006) and Agresti *et al*. (2008) interpreted that Receiver Operating Characteristics (ROC) curve are useful for organizing classifiers and visualizing the performance. ROC graphs are commonly used in decision making, and in recent years have been used increasingly in machine learning and data mining research. Hosmer and Lemeshow (2000) suggested area under the ROC curve and grades.

Table 1: Grades of ROC curve values

ROC	Grade
0.90-1	Excellent
0.80-0.90	Good
0.70-0.80	Fair
0.60-0.70	Poor

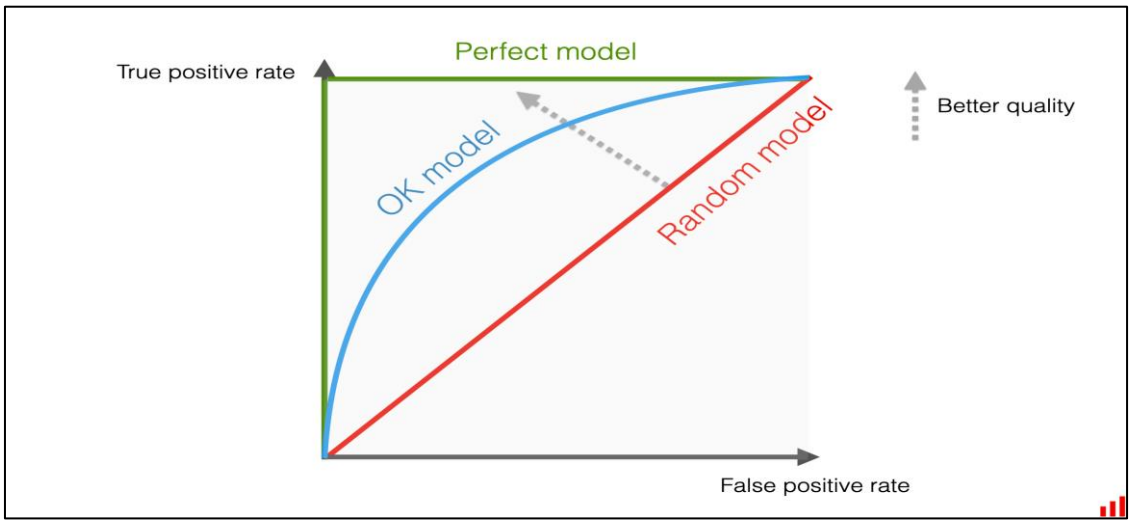


Figure 1: Ideal ROC curve by Fawcett (2006)

SPSS (2012) was used for statistical analyses and plot ROC curve for all data obtained.

3 RESULTS AND DISCUSION

Fiber Classifying System (FCS), Tomsic Fiber Tester (TFT) and MicroLab results are showed in Tables 2 and 3; Cotton fiber properties as seen for fineness and maturity characteristics with repeatability which represents the performance of one instrument over several times. Meanwhile Table 4 represents reproducibility as the performance of different instruments for the same sample.

In Table 2; FCS output gives micronaire value (Mic.), maturity ratio (MR), maturity percentage (M%) and linear density (LD) refers to the weight of length unit.

Both of Micronaire reading and maturity ratio outputs were screened at FCS and TFT. Meanwhile calculated for MicroLab. Micronaire reading among varieties means how fineness is, meanwhile micronaire reading within one variety identify the degree of maturity.

Micronaire reading mean values ranged from 3.68 to 3.99 for G 92 (the finest variety) in the first grade (FG) in FCS and TFT, respectively. On the other hand; FG grade for G 98 (the coarsest variety) ranged from 4.73 to 5.92 for TFT and MicroLab instruments, respectively. In addition to micronaire value, G 98 had the highest value for maturity ratio. whereas LD for all studied varieties declined from the highest grade (FG) to the lowest one (FGF).

In Table 3, both of perimeter and diameter were elaborated by MicroLab estimation then got wall thickness, micronaire and maturity ratio by calculation. Perimeter and diameter had the highest mean value for G 98, while G 92 had the lowest values. Nearly the same trend of perimeter and diameter was explained by Gordon *et al*. (2007) and Gordon *et al*. (2008). Results were expressed as mean ± standard error to indicate the precision of the estimated mean within each cotton variety. The lowest lint grade exhibited higher values of SE more than the higher grades, that means measurements of fineness and maturity of FCS, TFT and MicroLab were more accurate for the higher grades. In so much that the most effect is due to high content of trash in low cotton grades. On the other hand; describing the variability among observations results were expressed as mean ± standard deviation as seen in Table 4. In general; SD for Mic and MR increased from highest to lowest grade within each variety. Otherwise; there were a slight fluctuation may due to sample size, conditions of the instrument and the operator as seen for G 97 in FCS instrument.

Table 2: Repeatability of fineness and maturity in FCS and TFT

Varieties	Grades	Statistics	FCS (Wira output)				TFT (output)	
			Mic.	MR	M%	LD	Mic.	MR
G 92	FG	Mean	3.68	88.88	79.17	143.77	3.99	88.17
		Range	0.03	1.5	3.61	1.56	0.18	0.56
		SE	0.008	0.433	1.07	0.451	0.039	0.134
	G	Mean	3.23	83.92	74.94	132.55	3.49	84.22
		Range	0.02	9.53	5.89	1.90	0.07	0.56
		SE	0.006	2.91	1.87	0.549	0.016	0.136
	FGF	Mean	3.06	79.93	63.24	120.22	3.07	78.29
		Range	0.07	0.82	3.99	2.14	0.19	0.96
		SE	0.023	0.237	1.15	0.635	0.043	0.227
G 96	FG	Mean	4.01	87.23	77.22	162.09	4.22	85.00
		Range	0.04	1.10	1.11	1.40	0.13	0
		SE	0.013	0.356	0.353	0.452	0.029	0
	G	Mean	3.41	84.76	70.87	142.99	3.77	81.45
		Range	0.28	1	1	1.98	0.22	0.65
		SE	0.089	0.296	0.327	0.653	0.046	0.149
	FGF	Mean	2.96	78.41	66.33	132.41	3.15	75.26
		Range	0.07	2	2.74	2.66	0.28	0.56
		SE	0.021	0.584	0.866	0.799	0.059	0.115
G 97	FG	Mean	4.48	85.79	76.93	170.61	4.21	83.28
		Range	0.17	2.20	1.73	0.680	0.17	0.56
		SE	0.051	0.733	0.544	0.202	0.042	0.161
	G	Mean	4.14	82.09	70.93	153.97	3.76	79.29
		Range	0.07	3.73	1.15	1.18	0.30	0.85
		SE	0.023	1.11	0.364	0.382	0.067	0.201
	FGF	Mean	3.56	77.42	67.87	149.88	3.63	71.42
		Range	0.16	2.27	3.27	26.32	0.12	0.56
		SE	0.048	0.659	0.952	8.72	0.031	0.139
G 98	FG	Mean	4.83	90.34	82.22	167.93	4.73	86.75
		Range	0.08	1.24	7.11	1.31	0.19	1
		SE	0.025	0.369	2.35	0.380	0.041	0.250
	G	Mean	4.63	86.98	76.65	148.07	4.65	82.42
		Range	0.03	1.63	0.68	0.420	0.07	0.690
		SE	0.010	0.499	0.196	0.128	0.015	0.159
	FGF	Mean	4.07	81.17	70.93	138.08	4.23	76.63
		Range	0.11	0.530	3	0.390	0.10	0.640
		SE	0.037	0.175	0.889	0.121	0.023	0.134

The highest value of micronaire was for MicroLab followed by TFT and FCS. MicroLab had the lowest value of MR followed by FCS then TFT. In so much that; micronaire only is not sufficient for decision making where micronaire can be a confusing indicator because low micronaire readings could indicate either inherently fine fibers of different varieties or immature fibers of the same cotton variety. Conversely, high micronaire could be a result of either coarse thick-walled fibers or fine fibers that have a good secondary wall thickness.

Table 3: Repeatability of fineness and maturity attributes for MicroLab instrument

Varieties	Grade	Statistics	Measured		Calculated		
			Perimeter (microne)	Diameter (microne)	Cell wall thickness (degree)	Mic.	MR
G 92	FG	Mean	43.15	13.56	0.544	3.94	82.66
		Range	0.55	0.770	0.006	0.02	0.04
		SE	0.132	0.185	0.001	0.004	0.010
	G	Mean	42.38	12.30	0.501	3.88	79.48
		Range	0.720	0.990	0.014	0.01	0.80
		SE	0.165	0.231	0.003	0.002	0.169
	FGF	Mean	41.31	11.32	0.448	3.81	71.56
		Range	0.660	0.750	0.001	0.07	0.07
		SE	0.178	0.171	0.0001	0.017	0.014
G 96	FG	Mean	45.37	14.55	0.511	4.89	82.54
		Range	0.77	0.92	0.003	0.08	0.48
		SE	0.184	0.198	0.0007	0.019	0.111
	G	Mean	44.24	13.62	0.459	4.23	78.21
		Range	0.59	0.98	0.006	0.12	0.59
		SE	0.125	0.213	0.001	0.026	0.139
	FGF	Mean	43.63	12.11	0.437	3.94	74.62
		Range	0.90	0.21	0.005	0.14	0.96
		SE	0.209	0.061	0.001	0.033	0.226
G 97	FG	Mean	47.49	16.61	0.487	4.88	81.44
		Range	0.99	0.99	0.004	0.14	0.63
		SE	0.286	0.226	0.0009	0.036	0.147
	G	Mean	45.60	14.99	0.469	4.48	78.51
		Range	0.99	0.01	0.004	0.13	0.40
		SE	0.214	0.003	0.0009	0.031	0.094
	FGF	Mean	44.13	13.47	0.458	4.20	71.45
		Range	0.20	0.99	0.004	0.05	0.43
		SE	0.045	0.238	0.0009	0.011	0.097
G 98	FG	Mean	50.91	19.22	0.544	5.92	84.38
		Range	0.20	0.581	0.004	0.07	0.96
		SE	0.049	0.126	0.001	0.015	0.234
	G	Mean	49.97	18.63	0.515	5.48	80.58
		Range	0.11	0.992	0.003	0.02	0.07

		SE	0.026	0.216	0.0006	0.004	0.018
	FGF	Mean	48.54	17.11	0.435	4.41	74.45
		Range	0.89	0.153	0.003	0.12	0.33
		SE	0.199	0.035	0.0007	0.026	0.034

It is crucial to estimate the relation among cotton fiber properties of FCS, TFT and MicroLab to study the magnitude of correlation coefficient which can be an indicator of the more similarity of the three instruments. As seen in Table 5; almost highly significant and positive correlation coefficient between TFT with FCS compared to TFT with MicroLab measurements. All in all; TFT and FCS were more correlated than TFT with MicroLab.

Table 4: Reproducibility via standard deviation of Micronaire and Maturity Ratio in FCS, TFT and MicroLab

Variety	**Grade**	**Instruments**					
		FCS		TFT		MicroLab	
		Mic	MR	Mic	MR	Mic	MR
G 92	FG	0.015	0.750	0.079	0.268	0.009	0.021
	G	0.019	0.777	0.831	0.272	0.015	0.339
	FGF	0.111	0.811	0.985	0.455	0.035	0.429
G 96	FG	0.023	0.616	0.057	0	0.038	0.222
	G	0.154	0.912	0.093	0.298	0.053	0.279
	FGF	0.336	1.01	0.118	0.430	0.067	0.452
G 97	FG	0.089	1.27	0.083	0.323	0.072	0.294
	G	0.099	1.93	0.134	0.401	0.091	0.389
	FGF	0.183	1.14	0.461	0.778	0.122	0.494
G 98	FG	0.044	0.639	0.082	0.500	0.030	0.468
	G	0.017	0.866	0.091	0.819	0.229	0.835
	FGF	0.064	0.903	0.446	0.968	0.452	0.967

Table 5: Correlation coefficient matrix for Miconaire and Maturity Ratio in FCS, TFT and MicroLab

TFT with FCS					**TFT with MicroLab**					
Traits	MIC	MR	M%	LD	Traits	Perimeter	Diameter	Cell wall	Mic	MR
MIC	1	-	-	-	Perimeter	1	-	-	-	-
MR	0.966**	1	-	-	Diameter	0.978**	1	-	-	-
M%	0.694*	0.880**	1	-	Cell Wall	0.461	0.524*	1	-	-
LD	0.778**	0.506*	0.640*	1	Mic	-0.318	0.422	0.538*	1	-
					MR	0.461	0.524*	0.666**	0.904**	1

Receiver Operating Characteristic (ROC) curve for micronaire and maturity measurements of FCS, TFT and MicroLab for cotton varieties, and grades were illustrated in Figures 2, 3 and 4. A model with an area under the curve (AUC) equal to 0.90 and above indicates perfect discrimination, where both sensitivity and specificity reach optimal values. And the ROC curve approaches the upper-left corner of the graph demonstrate better balance for sensitivity and specificity and superior diagnostic performance. Meanwhile; in other cases, not herein; an AUC approaching 0 suggests poor classification performance, as the ROC curve lies below the diagonal or reference line, indicating incorrect classification performance where increases in sensitivity are associated with substantial losses in specificity. All details were in the

same trend with Capaldo *et al*. (2025) as illustrated for FCS, TFT and MicroLab instruments. A solid line showing how well accuracy for each instrument distinguishes cotton varieties and grades data as seen bellow at Figures 2, 3 and 4.

According to ROC curves; Table 6 showed the three models with nearly perfect discrimination, achieving maximum sensitivity and specificity where combines sensitivity and specificity in one

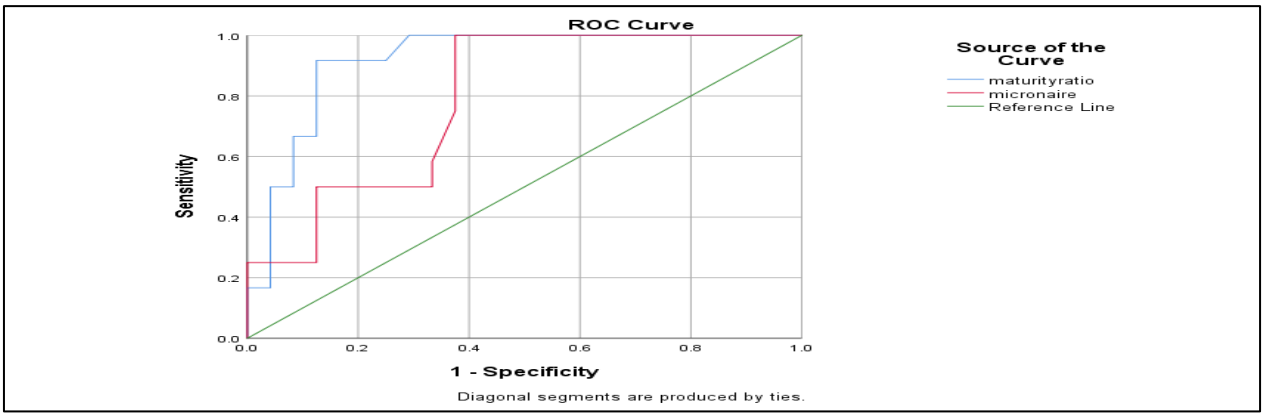


Figure 2: ROC curve for FCS of target varieties and grades

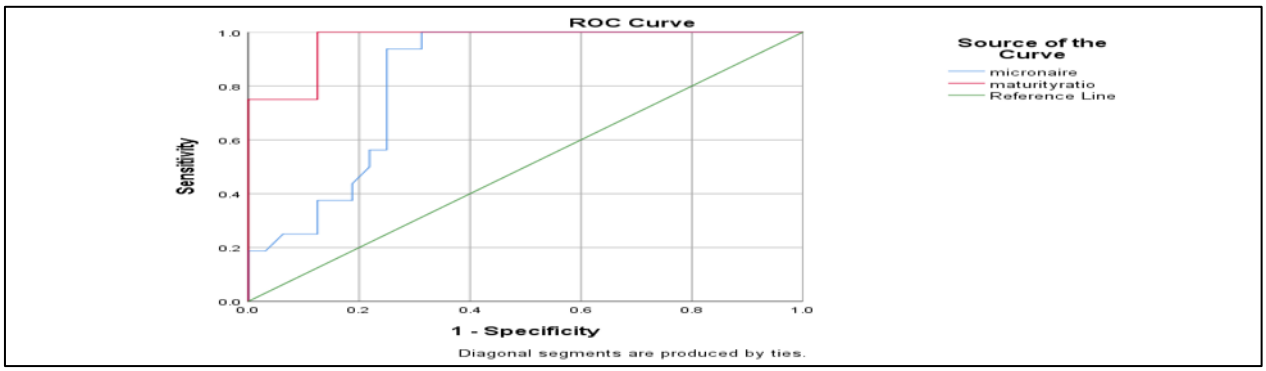


Figure 3: ROC curve for TFT of target varieties and grades

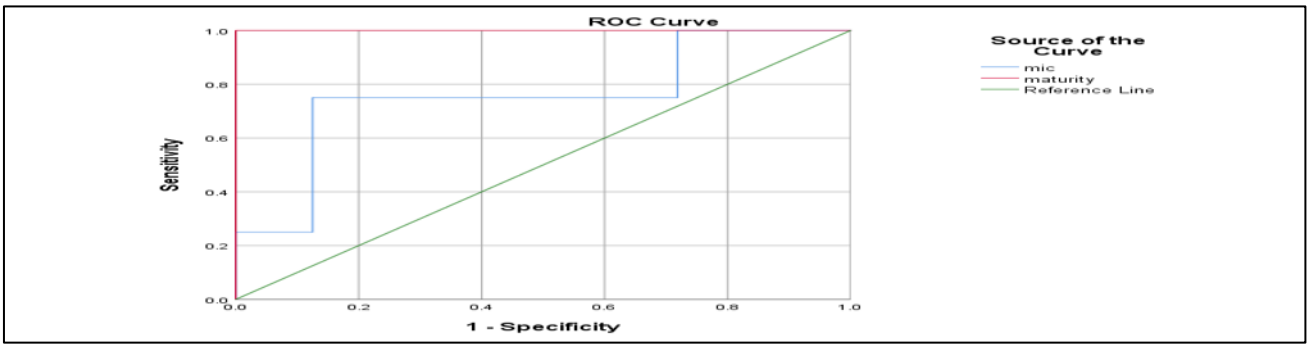


Figure 4: ROC curve for MicroLab of target varieties and grades

Table 6: ROC curve for FCS, TFT and MicroLab

Instruments	Properties	Area	S.E.	Asymptotic Sig.	Asymptotic 95% Confidence Interval	
					Lower Bound	Upper Bound
FCS	MIC	0.988	0.046	0.000	0.828	1.000
	MR	0.888	0.075	0.005	0.641	0.936
TFT	MIC	0.830	0.058	0.000	0.716	0.945
	MR	0.811	0.021	0.000	0.928	1.000
MicroLab	MIC	0.758	0.081	0.004	0.599	0.916
	MR	0.650	0.089	0.009	0.458	1.000

measure is the area under the curve (AUC) equals more than 0.8 and nearly 0.9 (good accuracy) for both of FCS and TFT then the least was for MicroLab. where sensitivity reaches its maximum value while specificity remains optimal, indicating correct classification of all cases of the instruments. All of FCS, TFT and MicroLab were with $p < 0.05$ that ensure that ROC curve was significantly better than chance. This gives a range where the true AUC is likely to fall 95% of the time. Lower Bound tends to the smallest plausible AUC and upper bound shows the largest plausible AUC as seen in Table 6. For FCS and TFT, differences of lower and higher bound were less than that for MicroLab. Ultimately, higher AUC values and ROC curves closer to the upper-left corner indicate better balance between sensitivity and specificity and superior model performance which arranged FCS the first then TFT and finally the lowest value was for MicroLab.

4 CONCLUSION

It is necessary to understand the properties of cotton accurately, not based on one instrument, but rather requiring the integration of more than one technology to obtain a complete panorama of the condition of cotton fibers. The proper selection of instruments depends on the objective, whether for classification, quality evaluation, or breeding purposes. Through comparisons, the best methods that ensure greater accuracy can be identified by improving quality and enhancing industrial performance. The main point of this study that TFT with FCS were more relevant than TFT with MicroLab and that give the necessity of integrating different instruments within cotton fiber testing centers and adopting standardized measurement protocols to ensure the accuracy of results. Generally; FCS and TFT are better for research and commercial studies on fineness and maturity. Meanwhile MicroLab is efficient for breeder to improve cotton varieties. For accurate cotton evaluation, integration of both systems and instruments gives stronger scientific and industrial base reliability.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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