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Original research article

ROLE OF PHOTOSYNTHETIC STABILITY AND PHYSIO-CHEMICAL ATTRIBUTES IN THE SELECTION OF IMPROVED COTTON GENOTYPES IN ACTUAL FIELD CONDITIONS

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Abstract: *The current experimental study was conducted at Cotton Research Station, Bahawalpur during the cotton growing in 2022. The study was designed to evaluate the elite cotton genotypes based on their photosynthetic sustainability and other physiochemical attributes which could help in framing a selection criterion for the development of improved carton genotypes. The results revealed that highly significant variations were present among the elite cotton genotypes for studied morpho-physiological, photosynthetic and biochemical traits i.e., CLCV incidence percentage, number of bolls, sympodia per plant, boll weight, net photosynthetic rate, total chlorophyll contents, transpiration rate, stomatal conductance, sugar contents, total phenolic contents, ascorbic acid and seed cotton yield, which could be used in devising selection criteria for this election of parental material to be used in the hybridization program. Furthermore, the correlation coefficient analysis unveiled the strong correlation of seed cotton yield with transpiration rate, sugar contents, stomatal conductance, net photosynthetic rate, ginning out turn and sympodia per plant whereas a strong negative correlation was found for total phenolic contents. These results were also verified through the mean bar graphs and biplot graphs which show that these traits have the highest influence on seed cotton yield under the optimal condition.*

Keywords: Correlation, Biplot Analysis, Stomatal Conductance, Transpiration rate, Antioxidants, sCLCuV.

Introduction

Cotton is one of the most adopted and globally cultivated field crops. It is not only cultivated for the production of lint but also for fuel and cooking oil. Hundreds and thousands of people are associated with this crop through its cultivation, processing and trade globally, which substantially contributes to the textile and cooking oil industry (1). Cotton crop is grown in over 70 countries around the world. However, its primary producers include India, China, the United States, Brazil, Pakistan and Uzbekistan. Besides these countries, many other countries also contribute to the global supply, each with varying level of production depending upon their socio-agricultural practices and prevailing climatic conditions (2).

Cotton production holds significant importance for Pakistan's economy and agriculture. In 2023-24, cotton was cultivated in an area of 2.4 million hectares against 2.1 million ha last year, showing a growth of only 13.1 percent (3). In contrast, its production recorded a remarkable increase of 108.2 percent to 10.2 million bales. Cotton crops contribute to 0.7 percent of GDP and 2.9 percent in agriculture value addition. The reason for higher cotton production in 2023-24 was the increased cultivated area, provision of good quality, pest-tolerant seeds, favourable environmental conditions, and attractive, support price of cotton (3). As one of the country's leading cash crops, cotton is a major source of foreign exchange and underpins the textile industry, which contributes substantially to Pakistan's GDP and export earnings. This sector employs millions, including farmers, labourers in ginning factories, and workers in textile mills, thereby supporting livelihoods and reducing poverty, particularly in rural areas (4). The textile industry, heavily reliant on cotton, encompasses a wide range of activities from ginning and spinning to

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weaving and garment manufacturing, playing a crucial role in the country's industrial landscape. Additionally, cotton exports, including yarn, fabric, and finished garments, bring in much-needed foreign currency, bolstering Pakistan's trade balance.
Although Pakistan's cotton per acre yield is improving, it is still quite low with respect to top-producing countries (5). The lower production and per acre yield of cotton in Pakistan stem from various challenges, including pest and disease infestations, poor-quality seeds, inefficient irrigation, soil degradation, outdated farming practices, and the impacts of climate change (6). Pests like the cotton bollworm and diseases such as cotton leaf curl virus significantly damage crops, while the use of uncertified seeds results in less resilient plants. Water scarcity and inefficient irrigation methods cause water stress, negatively affecting crop growth (7). Continuous cotton cultivation without proper soil management leads to nutrient depletion and reduced productivity. Additionally, many farmers rely on traditional farming techniques, lacking access to modern methods and technologies that could enhance yields. Climate change exacerbates these issues with unpredictable weather patterns and extreme temperatures. To improve cotton production, Pakistan needs to adopt integrated pest management practices, invest in high-quality, pest-resistant seeds, and implement efficient irrigation systems like drip and sprinkler irrigation. Moreover, increased investment in agricultural research and development is essential for innovation and long-term improvement in cotton farming.
Experiments involving the evaluation of elite genotypes can significantly contribute to sustainable cotton production and increased yields. By testing and analyzing these superior genotypes, one can identify cotton varieties that are more resistant to pests, diseases, and environmental stresses such as drought and extreme temperatures (8). These genotypes often possess traits that enhance growth, improve fiber quality, and increase overall productivity. The data gathered from these experiments allow for the development of optimized cultivation techniques tailored to the specific needs of high-performing genotypes. Consequently, the adoption of these advanced varieties by farmers can lead to higher yields, reduced production costs, and a more sustainable cotton industry that is better equipped to meet the challenges of changing climate conditions and resource limitations (9). The current study was planned to evaluate the five elite cotton genotypes based on their photosynthetic stability and physio-chemical attributes in the selection of improved cotton genotypes.

Methodology

The current experimental study was designed and executed at Cotton Research Station, Bahawalpur during the cotton crop growing season 2022. The experimental material had consisted of five elite cotton genotypes i.e., ELA-2201, ELA-2207, ELA-2212, ELA-2214 and ELA-2225 and the experiment was laid out under a randomised complete block design with treatments in triplicates. The sowing was done on beds where pant-to-plant and row-to-row distance was maintained at 30 cm and 75 cm, respectively. The sowing was done with the help of a dibbler @2 seeds per hill and at the early seedling stage, thinning was done to maintain optimum population density. The standard agronomic and other plant protectionary measures were carried out for all the genotypes under all three replications. The properties of soil and irrigation water used during the study are given in Table 1

Table 1: Properties of Soil and Irrigation water used during the study

Properties of Irrigation water used in the study		
Sr#	Parameter	Value
1	Total Soluble Salts (TSS)	1163 ppm
2	Sodium Adsorption Ratio (SAR	6.9
3	Residual Sodium Bicarbonate (RSB)	1.46
4	Chloride	4.4 meL
Properties of Soil on which the experiment was carried out		
1	Soil Texture	Clay Loamy
2	pH	7.9
3	EC	4.9 dSms
4	Organic Matter	0.74
5	Available P	7.6 ppm
6	Available K	84 ppm
7	Zinc	1.36 ppm

The data was recorded for several key morphological, physiological and biochemical parameters of cotton crops. The traits included CLCV incidence percentage, number of bolls, sympodia per plant, boll weight, net photosynthetic rate, total chlorophyll contents, transpiration rate, stomatal conductance, sugar contents, total phenolic contents, ascorbic acid and seed cotton yield. The CLCV incidence percentage was calculated using the formula used by Aslam et al. (2022). The photosynthesis-related parameters were measured using the hand-held photosynthesis system "CI-340 Handheld Photosynthesis System" developed by the CID-Bio-ScienceINC. Biochemical parameters i.e., sugar contents, total phenolic contents, ascorbic acid were measured through spectrometry.
The data obtained were subjected to analysis of variance, correlation coefficient analysis and biplot analysis as devised by Steel et al., (1997). The PC1/PC2 biplot analysis was used to categorise cotton genotypes on the basis of their performance as used by Hussain et al., 2024. To compute the inferences from these analyses, four statistical packages were used including Statistix 8.1, XLSTAT, OriginPro and Microsoft Excel.

Results and Discussion

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The analysis of the collected data indicated that a high degree of genetic variations were present among the cotton genotypes for studied plant morphological, physiological biochemical and photosynthesis-related parameters including CLCV incidence percentage, number of bolls, sympodia per plant, boll weight, gaining out turn, net photosynthetic rate, total chlorophyll contents, transpiration rate, stomatal conductance, plant sugar contents, total phenolic contents, ascorbic acid and seed cotton yield (Table 2). These results suggested that these variations among cotton genotypes for key cotton plant traits could successfully be used to develop new cotton varieties as well as to improve the existing cotton cultivars. Similar results were also reported by many cotton scientists who showed that cotton crops had significant variations for key cotton improvement traits. These traits could be used to improve cotton crops not only for productivity but also to develop climate-resilient cotton strains (5, 10-13)

Table 2: Mean Square (MS) of key plant traits in elite cotton genotypes

Source of Variation	Replication	Genotypes	Error
df/Traits	2	4	8
CLCuV Incidence Percentage (CLCV)	0.47	14.23**	1.13
Number of Bolls (NOB)	0.88	15.19**	1.53
Sympodia per Plant (SP)	15.78	10.11**	4.60
Boll Weight (BW)	0.07	0.05**	0.01
Ginning Out Turn (GOT)	3.92	12.07**	2.15
Net Photosynthetic Rate (Pn)	0.66	25.88**	1.50
Total Chlorophyll Contents (Total Chl)	0.14	0.17**	0.05
Transpiration Rate (Tr)	0.00	0.02**	0.00
Stomatal Conductance (Ci)	1837.3	5750.8**	199.5
Sugar Contents (Sugars)	5.48	20.70**	1.85
Total Phenolic Contents (TPC)	134.1	407.2**	52.1
Ascorbic Acid (ASA)	1638.2	3188.1**	309.2
Seed Cotton Yield (SCY)	2429.6	65044.3**	3107.0

The results obtained from the analysed data of cotton genotypes depicted that the highest net photosynthetic rate was observed in ELA-2201 (23.0 µmole m-2 s-1) followed by ELA-2214 (22.5 µmole m-2 s-1) while the lowest that photosynthetic rate was observed in ELA-2225 (16.3 µmole m-2 s-1) followed by ELA-2212 (17.7 µmole m-2 s-1) (Figure 1 a & b). The difference in net photosynthetic rate between cotton genotypes was significant and ELA-2201 and ELA-2214 had a significantly higher net photosynthetic rate than the rest of the cotton genotypes (ELA-2207, ELA-2212 and ELA-2225) (Figure 1 a & b).

Similarly, the highest chlorophyll contents were accumulated by ELA-2225 (1.9 mg g-1 F.w) and ELA-2214 (1.9 mg g-1 F.w) followed by ELA-2207 (1.8 mg g-1 F.w) and ELA-2201 (1.7 mg g-1 F.w) (Figure 1 a & b). However, the differences between cotton genotypes for total chlorophyll contents were not highly significant. Nevertheless, the lowest total chlorophyll content accumulation among cotton genotypes was observed in ELA-2212 (1.5 mg g-1 F.w) (Figure 1 a & b). Considering the transpiration rate of the cotton genotypes under the given conditions, ELA-2214 (0.43 m mole m-2 s-1) showed the highest transpiration rate followed by ELA-2201 (0.39 m mole m-2 s-1) and ELA-2207 (0.31 m mole m-2 s-1). The lowest transpiration rate was observed in ELA-2225 (0.25 m mole m-2 s-1) followed by ELA-2212 (0.27 m mole m-2 s-1).

In the case of stomatal conductance, values of two cotton genotypes namely ELA-2214 (276 m mole m-2 s-1) and ELA-2201 (257 m mole m-2 s-1) were much higher than the rest of the cotton genotypes (ELA-2207, ELA-2212 and ELA-2225) under the given condition (Figure 2 c & d). However, the lowest stomatal conductance was observed in cotton genotypes ELA-2225 (179 m mole m-2 s-1)

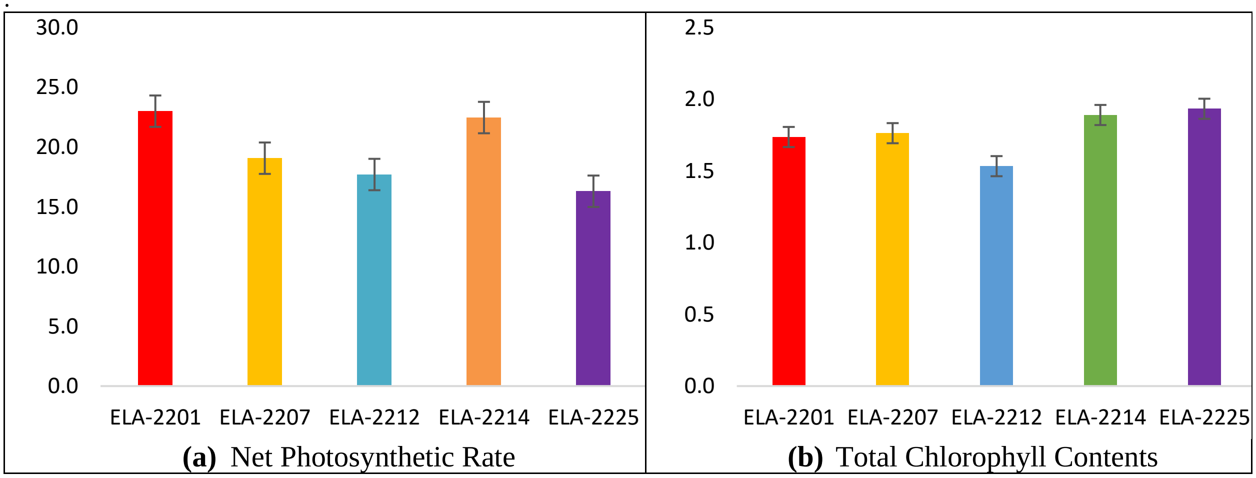

FIGURE 1 | Performance of Elite cotton genotypes based on (a) Net Photosynthetic Rate (b) Total Chlorophyll Contents

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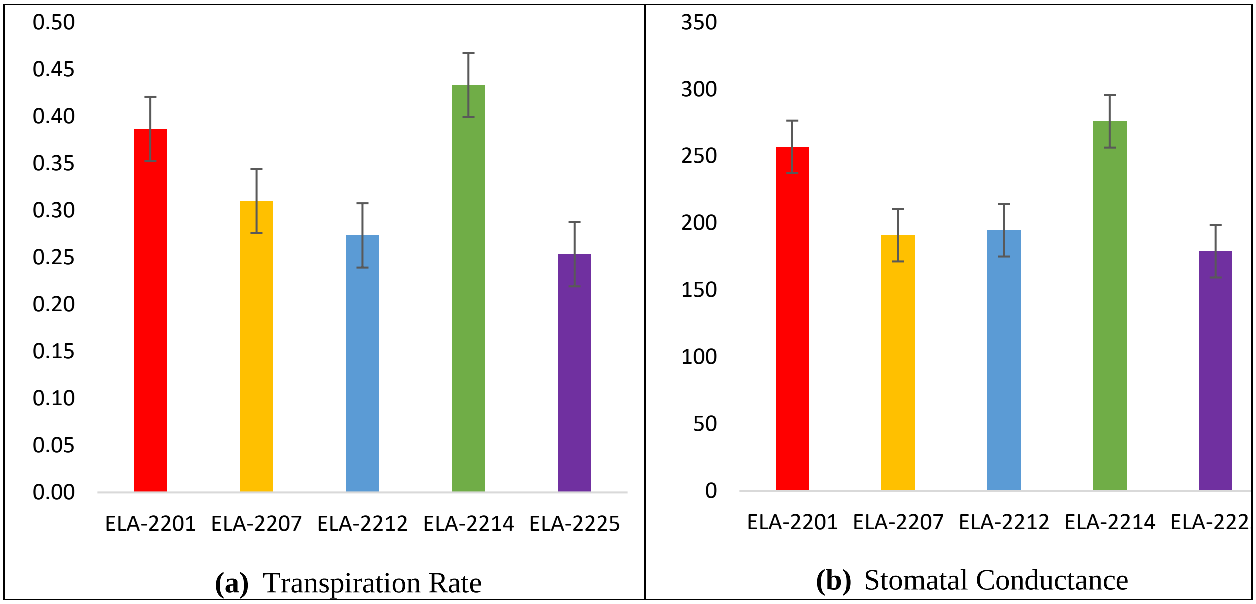

FIGURE 2 | Performance of Elite cotton genotypes based on (c) Transpiration Rate (d) Stomatal Conductance

The biochemical traits of cotton genotypes were also measured including sugar contents, total phenolic contents and ascorbic acid. The results revealed that ELA-2225 accumulated the highest sugar content (27.1 mg g-1 F.W) followed by ELA-2201 (25.5 mg g-1 F.W) while ELA-2225 accumulated the lowest sugar content (27.1 mg g-1 F.W) under the given condition followed by ELA-2212 (21.8 mg g-1 F.W) (Figure 3 e & f). Similarly, cotton genotype ELA-2225 accumulated the highest phenolic contents (81.6 µ mol/g FW) followed by ELA-2212 (75.2 µ mol/g FW) and ELA-2207 (73.2 µ mol/g FW) while the lowest phenolic contents were accumulated by ELA-2214 (54.3 µ mol/g FW) (Figure 3 e & f). One of the major, non-enzymatic antioxidants, Ascorbic acid showed significant differences among cotton genotypes for accumulation and results showed that the highest accumulation of ascorbic acid in ELA-2214 (638.0 µg g-1 FW) followed by ELA-2225 (606.3 µg g-1 FW) and ELA-2212 (591.0 µg g-1 FW) while lowest ascorbic acid accumulation was observed in ELA-2201 (550.3 µg g-1 FW) followed by ELA-2207 (578.0 µg g-1 FW) (Figure 4g).

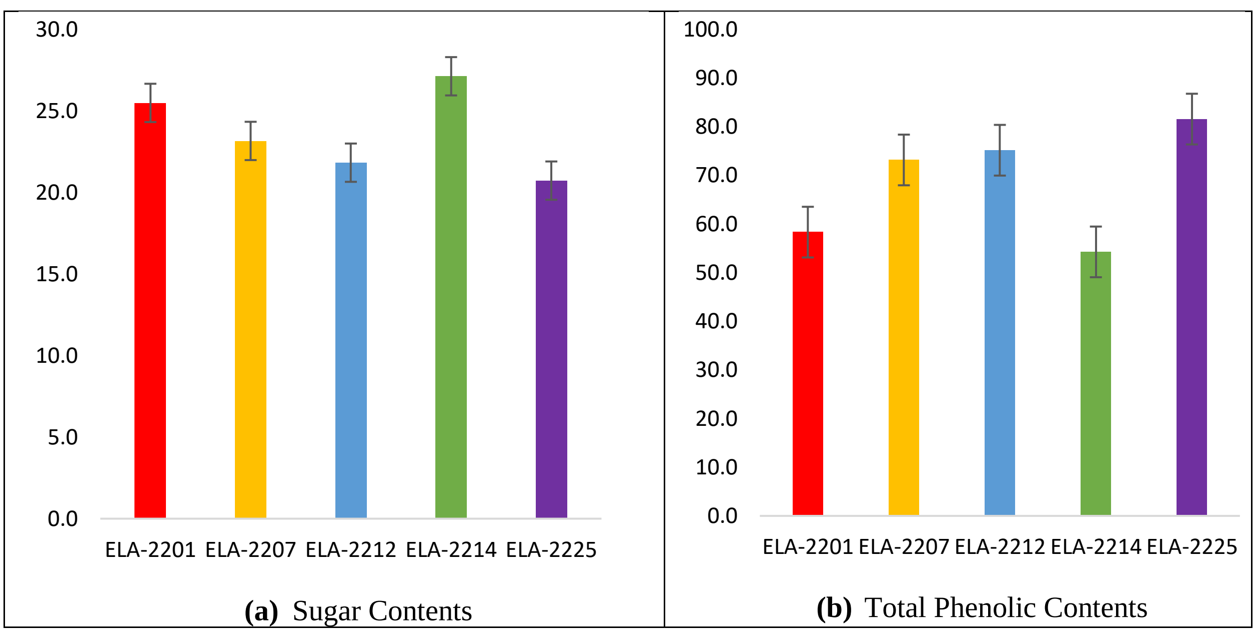

FIGURE 3 | Performance of Elite cotton genotypes based on (e) Sugar Contents (f) Total Phenolic Contents

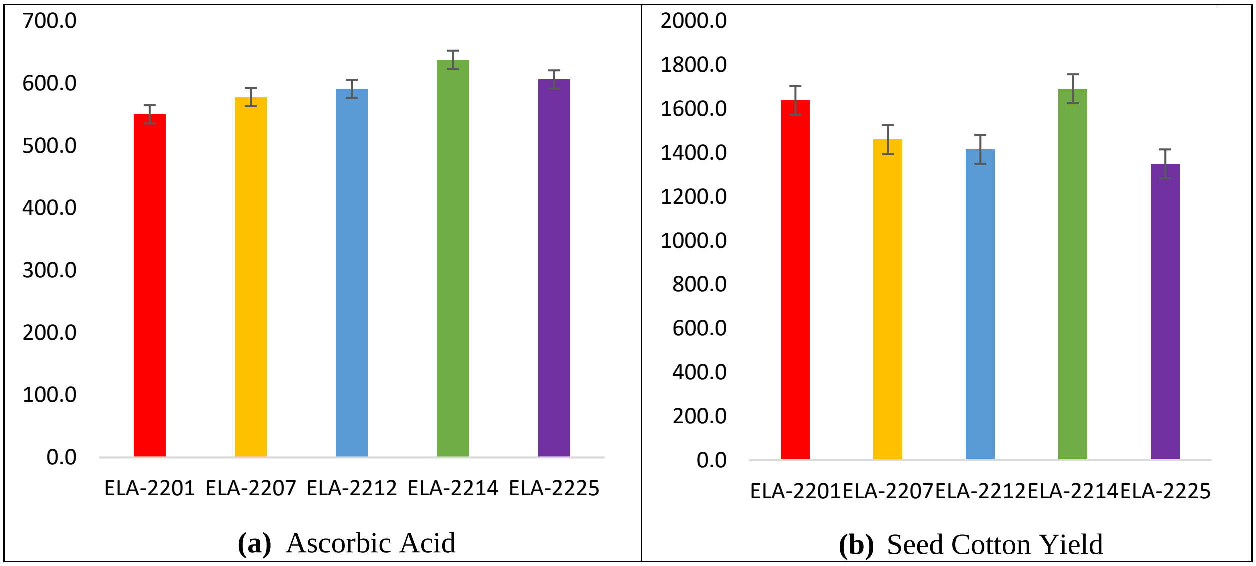

FIGURE 4 | Performance of Elite cotton genotypes based on (g) Ascorbic Acid (h) Seed Cotton Yield

The ultimate objective of the current study was to assess the performance of cotton genotypes and select the genotypes having better yield for the development of advanced cotton varieties. Therefore, the seed cotton yield is one of the most important traits that is influenced by several other associated traits. In the current study, the cotton genotype ELA-2214 showed the highest yield (1692 kg per hectare) followed by ELA-2201 (1639 kg per hectare) and ELA-2207 (1461 kg per hectare) while the lowest seed cutter yield was observed in cotton genotype ELA-2225 (1416 kg per hectare) (Figure 4h). These results depicted that the seed cotton yield is highly dependent on net photosynthetic rate total chlorophyll contents, transpiration rate, stomatal conductance, sugar contents and ascorbic acid accumulation while it has a negative association with total phenolic contents. Therefore, any cotton breeding program aiming to improve cotton production must include these traits for the selection of parents in Pedigree generations. Similar, results were also reported by many cotton scientists who showed that these traits must be included in the selection of parental material for cotton improvement.

Correlation coefficient analysis is one of the major statistical approaches to access the association/correlation of different cotton traits with each other and with seed cotton yield as used by several researchers (14-18). In current study, a strong correlation of seed cotton yield was found with transpiration rate (r = 0.993**), sugar contents (r = 0.992**), stomatal conductance (r = 0.983**), net photosynthetic rate (r = 0.979**), ginning out turn (r = 0.851**), and sympodia per plant (r = 0.793**) while a strong negative association was observed with total phenolic contents (r = -0.999**). The highest positive correlation was observed between sugar contents and transpiration rate (r = 0.997**) followed by seed cotton yield and transpiration rate (r = 0.993**). On the other side, the highest negative correlation was found between seed cotton yield and total phenolic contents (r = -0.999**) followed by transpiration rate and total phenolic contents (r = -0.988**). The findings of our research were in complete line with the results of Mohammed et al. (2015), Cornish et al. (1991), Zhang et al. (2017) and Ahmad et al. (2019) and showed a strong correction of transpiration rate, sugar contents, stomatal conductance, net photosynthetic rate, and total phenolic contents.

Table 3: Correlation coefficient between different plant traits in upland cotton genotypes

Variables	CLCV	NOB	SP	BW	GOT	Pn	T. Chl	Tr	Ci	Sugars	TPC	ASA
CLCV	1	0.164	0.463	-0.130	0.670	0.786	0.531	0.830	0.879	0.787	-0.816	0.173
NOB	0.164	1	0.667	0.932	0.360	0.364	-0.527	0.098	0.209	0.099	-0.228	-0.836
SP	0.463	0.667	1	0.543	0.809	0.865	-0.422	0.722	0.747	0.745	-0.807	-0.427
BW	-0.130	0.932	0.543	1	0.274	0.113	-0.765	-0.140	-0.012	-0.127	-0.007	-0.771
GOT	0.670	0.360	0.809	0.274	1	0.808	-0.202	0.809	0.897	0.809	-0.876	0.111
Pn	0.786	0.364	0.865	0.113	0.808	1	0.078	0.957	0.944	0.959	-0.976	-0.127
Total Chl	0.531	-0.527	-0.422	-0.765	-0.202	0.078	1	0.241	0.182	0.190	-0.116	0.465
Tr	0.830	0.098	0.722	-0.140	0.809	0.957	0.241	1	0.975	0.997	-0.988	0.161
Ci	0.879	0.209	0.747	-0.012	0.897	0.944	0.182	0.975	1	0.964	-0.987	0.153
Sugars	0.787	0.099	0.745	-0.127	0.809	0.959	0.190	0.997	0.964	1	-0.987	0.144
TPC	-0.816	-0.228	-0.807	-0.007	-0.876	-0.976	-0.116	-0.988	-0.987	-0.987	1	-0.075

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ASA	0.173	-0.836	-0.427	-0.771	0.111	-0.127	0.465	0.161	0.153	0.144	-0.075	1
SCY	-0.522	0.209	0.793	-0.024	0.851	0.979	0.151	0.993	0.983	0.992	-0.999	0.074

Note: Values in bold are highly Significant

PC1/PC2 biplot analysis is a part of principal component analysis which is used to characterize and classify crop genotypes into different groups based on their performance and genetic diversity. In the current study, the PC1/PC2 biplot analysis showed that these two principal components (PC1 and PC2) have 90% of the total variability related to the data. The biplot analysis also showed that seed cotton yield had a strong association with stomatal conductance, sugar contents, net photosynthetic rate, ginning out turn, sympodia per plant, total chlorophyll contents and ascorbic acid accumulation due to the lower angle between seed cotton field and these traits. Furthermore, biplot analysis also showed that cotton genotypes ELA-2201 and ELA-2214 were the most productive cotton genotypes among the studied elite cotton genotypes due to the corresponding position of these genotypes on the graph which is away from the centre of origin of the biplot graph and has lower angle with the seed cotton yield. Moreover, this is also evident from the fact that besides these two genotypes, the other three genotypes correspond to the different quadrics of the graph. Biplot analysis is one of the most used biometrical approaches by plant scientists to categorize, classify and characterize germplasm based on their performance, genetic diversity, disease susceptibility and other differentiating traits (22; 9; 16; 20and 15).

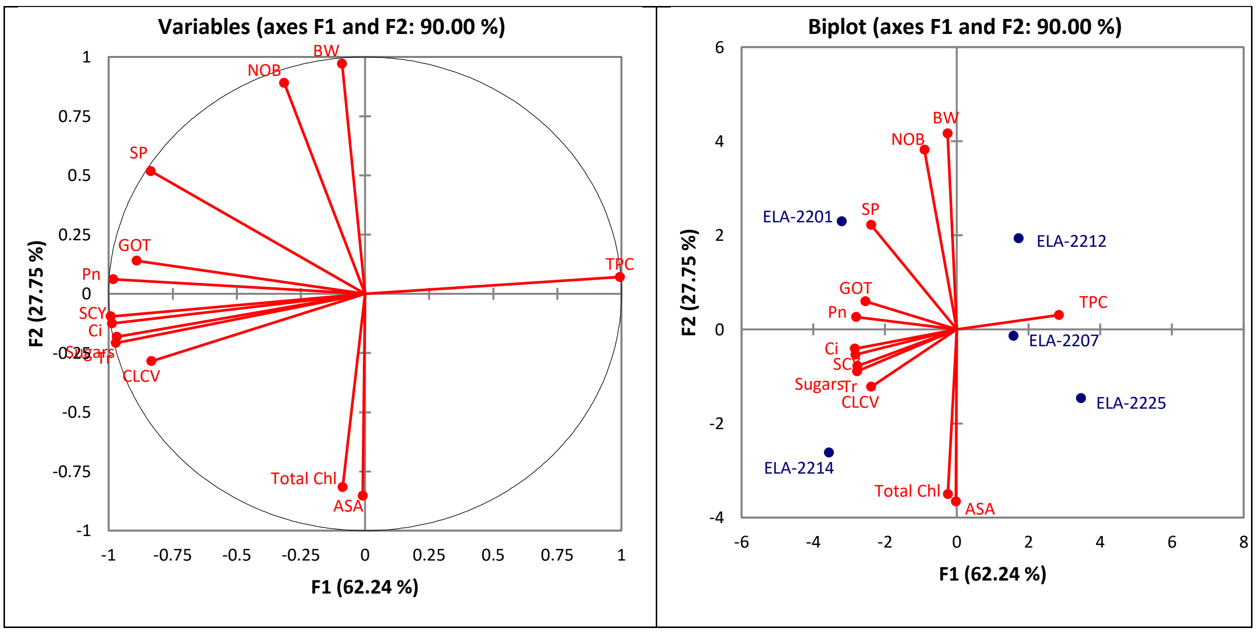

Figure 2: PC1/PC2 Cumulative Biplot between plant traits and cotton genotype

Conclusion

The current experimental study was designed to evaluate the elite cotton genotypes based on their photosynthetic sustainability and other physiochemical attributes which could help in framing a selection criterion for the development of improved carton genotypes. The results revealed that highly significant variations were present among the elite cotton genotypes for studied morpho-physiological, photosynthetic and biochemical traits which could be used in devising selection criteria for this election of parental material to be used in the hybridization program. Furthermore, the correlation coefficient analysis unveiled the strong correlation of seed cotton yield with transpiration rate, sugar contents, stomatal conductance, net photosynthetic rate, ginning out turn and sympodia per plant whereas a strong negative correlation was found for total phenolic contents. These results were also verified through the mean bar graphs and biplot graphs which show that these traits have the highest influence on seed cotton yield under the optimal condition. Therefore, these traits must be included in devising selection criteria for any breeding/hybridization, aiming to improve seed cotton yield in cotton crop.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.
Ethics approval and consent to participate.
Approved by the department Concerned.
Consent for publication
Approved

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Conflict of interest

The authors declared an absence of conflict of interest.

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