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CHANGES IN PHYSIOLOGICAL PARAMETERS IN COLORED-FIBER COTTON ACCESSIONS AND THEIR ANALYSIS

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Abstract

This study examined physiological traits of cotton (Gossypium hirsutum L.) accessions that differ in fiber color. The material comprised the brown-fibered accession A-1025 and the white-fibered Gulshan, both from the collection of the Institute of Genetics and Plant Experimental Biology (Academy of Sciences of the Republic of Uzbekistan), and the green-fibered accession 010764 from the collection of the Institute of Cotton Breeding, Seed Production and Cultivation Agrotechnologies (Ministry of Agriculture of the Republic of Uzbekistan). Total leaf water content was measured at the flowering–boll formation stage under optimal water supply, simulated drought and salinity. Under optimal supply it was 75.8% in 010764 and Gulshan and 71.9% in A-1025. Drought lowered it by 6.1, 7.0 and 1.9 percentage points in 010764, Gulshan and A-1025, respectively, and salinity by 5.7, 5.6 and 0.8 points, so A-1025 changed least under both stresses. Correlations among morphophysiological and economically important traits were also calculated, and the fuzz type and fiber color of three F_1 combinations involving 010764 were described.



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1. Introduction

Cotton is one of the main industrial crops of Uzbekistan, and breeding programs here have traditionally concentrated on yield, earliness and fiber quality. In recent years the picture has become more complicated. Two constraints increasingly shape cotton production in Central Asia: a shortage of irrigation water and the secondary salinization of irrigated soils. Both limit the water a plant can actually take up, and both show up first in the water status of the leaves. In irrigated cotton fields of the Aral Sea Basin in Uzbekistan, for example, modeling has shown that shallow groundwater supplies a large share of the crop's water use and so eases water stress, but at the price of increasing soil salinization [1].

Total leaf water content is one of the simplest physiological indicators of this status. It reflects the balance between water uptake by the roots and water lost through transpiration, and it reacts quickly to changes in soil moisture and salt concentration. It is especially informative at flowering and boll formation, when the plant's demand for water is highest and a deficit can directly affect the setting and filling of bolls. Measuring it in contrasting genotypes is a practical first step toward finding out which of them cope better with stress.

Naturally colored cotton has been grown since about 2300 BC [2]. Interest in it persists today: many studies look at colored-fiber accessions as a source of natural fabrics, which also offers economic advantages. Fabrics made from naturally colored cotton (NCC) do not lose color in washing; if anything, the color becomes more stable [3]. Cotton with colored fiber also has drawbacks. Its fiber differs from that of ordinary upland cotton in several technological properties, being often shorter, finer and weaker. Such cultivars may have smaller bolls and a lower

lint percentage, which can reduce total yield. Isolines of cotton that differ in fiber color have been compared for yield, fiber quality and photosynthesis [4].

Commercial growing and industrial use further run into problems with fiber color parameters, high wax content, the need for isolation distances, a limited range of colors [5, 6], and poor color stability across agroclimatic conditions and growing seasons. Stronger breeding research is therefore needed if this ecologically promising crop is to be used commercially, especially work on the inheritance of agronomic traits, fiber quality and color uniformity [7]. The main obstacle to wide industrial use, however, has less to do with marketing than with the need for specialized equipment that can process white and colored fibers separately, and for corresponding regulatory requirements [8].

Most of this work has dealt with fiber color and fiber quality. Far less is known about how accessions with different fiber colors respond to water deficit and salinity, although this knowledge would help decide which of them are worth including in breeding programs for stress-prone regions.

The aim of this study was to examine changes in physiological parameters, in particular total leaf water content under different water supply conditions, in G. hirsutum L. accessions with different fiber colors, and to determine correlations among morphophysiological and biochemical traits.

2. Materials and Methods

2.1. Plant material

Three accessions of G. Hirsutum L. That differ in fiber color were studied (Table 1). The brown-fibered A-1025 and the white-fibered Gulshan come from the collection of the Institute of Genetics and Plant Experimental Biology, Academy of Sciences of the Republic of Uzbekistan. The green-fibered 010764 comes from the collection of the Institute of Cotton Breeding, Seed Production and

Cultivation Agrotechnologies, Ministry of Agriculture of the Republic of Uzbekistan. Gulshan, with ordinary white fiber, served as the reference for the two colored accessions.

Table 1. Cotton accessions used in the study

Accession	Fiber color	Source collection
A-1025	Brown	Institute of Genetics and Plant Experimental Biology, Academy of Sciences of the Republic of Uzbekistan
Gulshan	White	Institute of Genetics and Plant Experimental Biology, Academy of Sciences of the Republic of Uzbekistan
010764	Green	Institute of Cotton Breeding, Seed Production and Cultivation Agrotechnologies, Ministry of Agriculture of the Republic of Uzbekistan

2.2. Experimental site, design and treatments

The experiment was carried out under field conditions at the Zangiota experimental station of the Institute of Genetics and Plant Experimental Biology (Tashkent Province), following the design described earlier for the same station [9]. Seeds were sown by hand to a depth of 4–5 cm in a 90 × 20 × 1 scheme, in three randomized replications, each consisting of one row of 15 hills, on each water-supply background.

Total leaf water content was determined at the flowering–boll formation stage under three conditions. Under optimal water supply (Variant I, control) plants received four irrigations in a 1:2:1 scheme, 4800–5000 m³/ha in total. Under simulated drought (Variant II) they received two irrigations in a 1:1:0 scheme, 2800–3000 m³/ha in total; drought was created by reducing the number of irrigations during flowering and boll formation and by withholding water at

ripening. All other agronomic practices were the same on both backgrounds. Measurements were made at the same time on both backgrounds, when soil moisture was 70–72% of field water capacity under optimal supply and 48–50% under drought. Salinity (Variant III) was studied in lysimeters filled with saline soil brought from Syrdarya Province, with the water supplied to the lysimeters recorded by electronic flow meters.

2.3. Determination of total water content

Total leaf water content was determined gravimetrically by the method of Tretyakov et al. [10] on leaves sampled at the flowering–boll formation stage, and was expressed as a percentage of fresh leaf mass, (FW − DW) / FW × 100, where FW is the fresh weight and DW the dry weight of the sample.

2.4. Statistical analysis

Data were processed statistically following Dospekhov [11]. Correlations among morphophysiological and biochemical traits were calculated in Microsoft Excel. A correlation was regarded as weak at $|r| < 0.3$, moderate at 0.3–0.7 and strong at $|r| > 0.7$.

3. Results and Discussion

3.1. Total leaf water content under different water supply conditions

Total leaf water content at the flowering–boll formation stage differed among the accessions and among growing conditions (Table 2, Figure 1).



Table 2. Total leaf water content in colored-fiber cotton accessions at the flowering–boll formation stage

Accession	Total leaf water content, %			Difference from Variant I, percentage points	
	Optimal supply (I)	Simulated drought (II)	Salinity (III)	II	III
010764 (green fiber)	75.8	69.7	70.1	−6.1	−5.7
Gulshan (white fiber)	75.8	68.8	70.2	−7.0	−5.6
A-1025 (brown fiber)	71.9	70.0	71.1	−1.9	−0.8

Note: Variant III compared with Variant II, percentage points: 010764, +0.4; Gulshan, +1.4; A-1025, +1.1.

Under optimal water supply, total leaf water content was 75.8% in both 010764 (green fiber) and Gulshan (white fiber), and 71.9% in A-1025 (brown fiber). Under simulated drought it was 69.7% in 010764, 68.8% in Gulshan and 70.0% in A-1025. Compared with optimal conditions, the largest decrease was in Gulshan (7.0 percentage points), followed by 010764 (6.1) and A-1025 (1.9).

Under salinity, water content was 71.1% in A-1025, 70.1% in 010764 and 70.2% in Gulshan. The corresponding decreases relative to optimal conditions were 0.8 points in A-1025, 5.7 in 010764 and 5.6 in Gulshan. In all three accessions, water content under salinity was slightly higher than under drought (by 0.4, 1.4 and 1.1 points in 010764, Gulshan and A-1025), so the simulated drought treatment was the harsher of the two in this experiment.

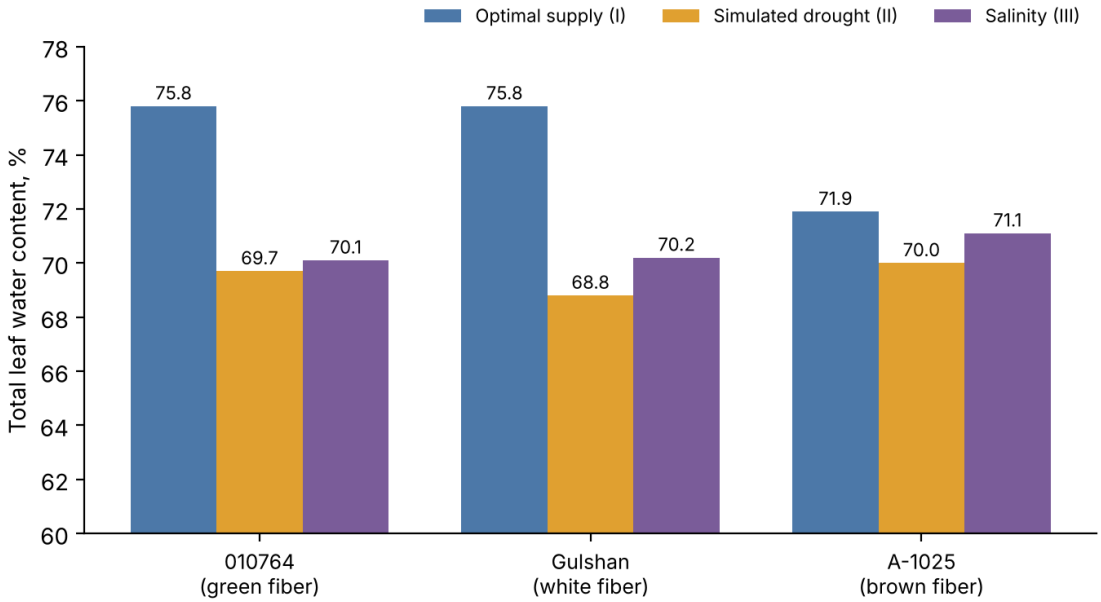


Figure 1. Total leaf water content by accession and treatment. The vertical axis starts at 60% to make the differences visible.

3.2. Relative changes

Because A-1025 started from a lower value than the other two accessions, absolute differences alone can mislead: a plant that begins with less water in its leaves has, in a sense, less to lose. Expressing each decrease as a share of the optimal value takes this into account (Table 3). Under drought the loss amounted to 9.2% of the optimal value in Gulshan, 8.0% in 010764 and 2.6% in A-1025. Under salinity the figures were 7.4%, 7.5% and 1.1%, respectively. The ranking therefore does not change: A-1025 lost several times less water, in relative terms, than either of the other accessions.

Table 3. Decrease in total leaf water content as a percentage of the optimal-supply value (calculated from Table 2)

Accession	Simulated drought, %	Salinity, %
010764 (green fiber)	8.0	7.5
Gulshan (white fiber)	9.2	7.4
A-1025 (brown fiber)	2.6	1.1

3.3. Interpretation

The data show that leaf total water content in the accessions changes with growing conditions. Under drought in particular, A-1025 changed relatively little compared with optimal conditions. Under both stresses it also had the highest absolute water content of the three accessions, although the margin was small, about 0.3–1.2 points under drought and about 0.9–1.0 under salinity.

The present data cannot say why A-1025 behaved this way, but several explanations are worth considering. A plant can hold on to leaf water under stress through osmotic adjustment, tighter stomatal control or a denser cuticle and wax layer; in upland cotton, drought-tolerant genotypes have been reported to keep a higher relative water content and to accumulate more proline [12]. Flavonoids, which also have antioxidant functions, are involved in plant responses to drought, salinity and other environmental stresses [13]. Brown fiber color is associated with proanthocyanidins, a class of flavonoid compounds [14, 15]; a report on colored cotton, for example, gives a flavonoid concentration of 8.67 mg/g in brown fiber against 3.12 mg/g in white [16]. A connection with stress behavior is therefore conceivable, but at this stage it is only a hypothesis and needs direct testing.

Physiological and biochemical traits of colored-fiber cotton have been studied by a number of local and foreign researchers. White-fibered cotton, for example, had the longest fibers (3.07 cm) and the highest cellulose content (915.81 mg/g) among isogenic lines differing in fiber color, whereas the colored lines had shorter fibers (2.54 and 2.48 cm) and less cellulose (787.63 and 780.66 mg/g) [16]. Flavonoid concentration also differed markedly: it peaked at 8.67 mg/g in brown and 7.13 mg/g in green fiber at 5 days post-anthesis, against 3.12 mg/g in white fiber [16].

3.4. Hybrid combinations

The fuzz type and fiber color of F_1 combinations obtained by crossing colored-fiber accessions with white-fibered cultivars in a full diallel scheme are given in Table 4. Heterosis breeding has been used before to modulate morphological and biochemical traits in colored cotton [6]. All three combinations showed full fuzz. Fiber color varied among them: the combination of A-1025 with 010764 was brown, Sadaf × 010764 was greenish, and Gulshan × 010764 was light brown.

Table 4. Fuzz type and fiber color of F_1 hybrid combinations

No.	F_1 combination	Fuzz type	Fuzz color
1	Gulshan × 010764	Full fuzz	Light brown
2	A-1025 × 010764	Full fuzz	Brown
3	Sadaf × 010764	Full fuzz	Greenish

3.5. Correlation analysis

Correlation analysis of colored- and white-fibered accessions showed associations of varying strength among some morphological and economically important traits (Table 5). Main stem height and the number of fruiting branches

were moderately and positively correlated (r = 0.48). The length of the growing period and the number of bolls per plant were moderately and negatively correlated (r = −0.67), which points to a complex relationship between the duration of the vegetation period and the formation of yield components.

The length of the growing period was also positively correlated with seed cotton weight per boll (r = 0.52, moderate) and with fiber length (r = 0.82, strong). The duration of plant development may therefore change together with some yield and fiber quality traits. Seed cotton weight per boll showed moderate positive correlations with 1000-seed weight (r = 0.60) and fiber length (r = 0.61), confirming a link between yield components and fiber quality.

Table 5. Correlations among morphological and economically important traits

Trait pair	r	Strength and direction
Main stem height – number of fruiting branches	0.48	Moderate, positive
Growing period – number of bolls per plant	−0.67	Moderate, negative
Growing period – seed cotton weight per boll	0.52	Moderate, positive
Growing period – fiber length	0.82	Strong, positive
Seed cotton weight per boll – 1000-seed weight	0.60	Moderate, positive
Seed cotton weight per boll – fiber length	0.61	Moderate, positive

These correlations describe the accessions as a group and say nothing about causation. The strong link between the length of the growing period and fiber length is the most interesting of them for breeders, since it suggests that selection

for earliness may come at some cost to fiber length. The negative link with the number of bolls per plant is harder to interpret and should be checked on a larger set of genotypes.

3.6. Limitations

Several limitations should be kept in mind. Only three accessions were studied, and total leaf water content was measured at one growth stage. The differences between accessions are in places small, about one percentage point, and a formal test of their significance requires replicated measurements with a measure of variability. Total water content is also only one aspect of plant water relations; parameters such as osmotic potential, proline content, membrane stability and chlorophyll content would give a fuller picture. Finally, the study did not measure yield or fiber quality under stress, so conclusions about practical tolerance are premature.

4. Conclusions

Total leaf water content at the flowering–boll formation stage varied with water supply conditions in the brown-fibered A-1025, the green-fibered 010764 and the white-fibered Gulshan. Under optimal supply the highest values were in 010764 and Gulshan (75.8%), against 71.9% in A-1025. Under simulated drought A-1025 had 70.0%, only 1.9 points below its optimal value, whereas 010764 and Gulshan fell by 6.1 and 7.0 points. Under salinity, water content was 71.1% in A-1025, 70.2% in Gulshan and 70.1% in 010764. Expressed as a share of the optimal value, the decrease in A-1025 was several times smaller than in the other two accessions under both stresses.

The accessions thus respond differently to changes in water regime. Analyzing these parameters together with other morphophysiological and biochemical traits

would allow a deeper assessment of the biological differences among them. In future breeding and genetic work with these accessions, physiological, morphological and fiber quality traits should be evaluated together, and tolerance to unfavorable environmental factors should be taken into account.

Declarations

Author contributions: both authors contributed to the conception of the study, the analysis of the data and the writing of the manuscript, and both approved the final version. Funding: the work was carried out within the fundamental research project FZ-2021100758 of the Institute of Genetics and Plant Experimental Biology, Academy of Sciences of the Republic of Uzbekistan. Conflict of interest: the authors declare no conflict of interest. Data availability: the data supporting the findings of this study are available from the corresponding author on reasonable request.

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