PHOTOSYNTHESIS AND COTTON FIBER QUALITY

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Abstract

Relationships between some important photosynthetic traits and fiber-quality characteristics were studied in inbred lines of Upland cotton. High positive correlations were found between photosynthetic activity components and cotton fiber properties, *i.e.*, higher photosynthetic carbon exchange rates, net assimilation rates, leaf areas, and specific leaf weights resulted in longer and finer fiber. Negative correlations were found between photosynthetic traits and fiber breaking strength.

Introduction

Crop yield and quality are highly dependent upon photosynthetic efficiency. The dependence of crop yield on photosynthetic efficiency has been described in many traditional works on photosynthesis [Govindjee, 1982], but much less attention has been paid to the relationships between photosynthesis and the quality of the crop that is the photosynthetic product. Therefore, the goal of this research was an examination of the possible relationships between cotton photosynthetic traits and fiber quality.

Materials and Methods

The study was carried out on inbred lines and commercial varieties of Upland cotton (*Gossypium hirsutum*, L.) that differ significantly in photosynthetic and economically important characteristics. Morphological and physiological characteristics of the photosynthetic appartus and productivity were determined by standard methods. Carbon exchange rates were measured by an infrared gas analyzer [INFRALIT, Germany]. The quality characteristics of the cotton fiber was determined by methods developed at the Central Scientific Research Institute of the Cotton-Paper Industry [Moscow]. Correlation and regression analyses were carried out using the statistical graphical software, STATGRAF.

Results

The results of the carbon exchange rate [CER], specific leaf weight [SLW], leaf area [LA], and net assimilation rate [NAR] studies of the inbred lines and commercial varieties are presented in Table 1. The data in Table 1 demonstrate clear differences in the photosynthetic capacities [CER and NAR] of the cotton genotypes in this study. These genotype differences were apparent at all stages of plant development, *i.e.*, squaring, flower anthesis, and boll ripening. Regardless of developmental stage tested, the highest photosynthetic capacity was observed in the L-601 line and the lowest photosynthetic capacity was found in the L-3 line, . The smaller leaf area of L-461 resulted in the highest NAR, but L-3, for which leaf area was less than 23% that of L-601 and Tashkent-1, consistently exhibited the lowest NAR [~70% of the L-601 NAR and ~77% of Tashkent-1 NAR, respectively].

Fiber-quality test results [fineness, strength, breaking length, and staple length] are presented in Table 2. Fineness is reported in reciprocal European metric units as meters/gram where the more familiar U.S. millitex is micrograms/meter. The L-601 line and the Tashkent-1 variety yielded fiber of the best quality, *i.e.*, Grade V fineness. These genotypes have long white fiber with high breaking lengths. The aerial plant parts of the L-3 and L-549 lines contained high levels of anthocyanin and had short, coarse fibers with brown coloration. [Grade VI fineness].

Fiber breaking length is a European method of expressing fiber strength as the length of fiber or yarn whose weight is equal to the breaking strength of the same fiber or yarn. Count-strength Product and tenacity are measures of breaking length and are comparable when expressed in similar units. Thus, L-601 and Tashkent-1 could be said to have the highest tenacities and L-549 the lowest. The longest fiber was produced by L-461, followed by L-601 and Tashkent-1.

Comparative analyses of photosynthetic and fiber-quality characteristics in Tables 1 and 2 indicate that CER and LA were positively correlated with fiber fineness, regardless of developmental stage [Table 3]. Fiber fineness and SLW were positively correlated at flowering and boll-ripening stages. Weaker positive correlations were found between NAR and fiber fineness, and plant developmental stage was not a factor in this relationship. There was a particularly close correlation between CER and fiber fineness [$r = 0.75$]. This relationship is described as a linear regression in Figure 1a. Higher photosynthetic efficiency quantified as CER resulted in finer fiber, results that agree with literature reports of a *G. mexicanum* subspecies with high fiber fineness [*ca.* 9500] and high CER [54 mg CO_2/dm^2h] (El-Sharkaway *et al.*, 1965; Nasyrov *et al.*, 1983].

Fiber strength was negatively correlated with CER and SLW, and these relationships weakened with increasing plant age [Table 3]. NAR and LA were not closely related to fiber strength. Fiber breaking length [tenacity] was more closely related to NAR and LA than to CER and SLW. Fiber length was most closely and positively related to NAR, and there was no connection between fiber length and LA.

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Specific leaf weight, an index of the status and content of the structural and functional elements of leaf mesostructure, was also closely related to the fiber properties of fineness and strength. Breaking length [tenacity] and staple length were more closely related to NAR and LA.

Breeders rely on visual and organoleptic screening for the best genotypes and depend heavily on experience and intuition. Since cotton breeders are unaware of these correlations between fiber quality and photosynthetic capacity, genotype selection frequently favors plants with thick leaves of dark-green color, *i.e.*, leaves of high SLW. However, new cotton lines selected and bred according to such highly subjective selection processes often exhibit increased yields and improved fiber quality. For the cotton genotypes in this study, high SLW and LA correlated positively and closely with fiber fineness [Table 3]. Correlations between leaf characteristics and fiber breaking strength were negative, and only SLW was related to fiber length. The net assimilation rate, NAR, was most closely correlated with fiber length, regardless of plant developmental stage. [Figure 1c.] Positive correlations were also found between NAR and fineness and breaking length, but NAR and fiber strength were unrelated [Table 3].

Conclusions

Thus, there are relatively close linear relationships between cotton photosynthetic traits and the quality of cotton fiber. The higher the photosynthetic gas exchange rate, leaf area, specific leaf weight, or net assimilation rate, the longer and finer are the cotton fibers. The results reported here have potential applications as morpho-physiological tests for the evaluation and selection of genotypes in cotton breeding.

References

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Table 1. Photosynthetic traits of inbred cotton lines and commercial varieties.

Line or Variety	Photosynthetic Traits					
	Carbon Exchange Rate			Specific Leaf Weight		
	1*	2	3	1	2	3
	--- mg $CO_2/dm^2 \cdot h$ ---			-------- g/dm^2 --------		
L-3	21.9	20.8	20.6	0.78	0.53	0.48
L-461	33.9	33.3	32.7	0.74	0.66	0.58
L-501	39.6	37.9	36.2	0.82	0.73	0.64
L-549	36.7	33.6	30.5	0.75	0.67	0.58
L-601	40.3	40.1	39.8	0.76	0.73	0.69
Tashkent-1	38.2	34.9	31.5	0.73	0.66	0.59
	Leaf Area			Net Assimilation Rate		
	------ dm^2/plant ------			-------- $g/m^2 \cdot d$ --------		
L-3	19.2	21.8	22.1	7.2	7.5	6.9
L-461	8.4	8.5	9.03	10.5	11.3	10.2
L-501	27.1	27.6	31.7	10.3	10.5	9.9
L-549	18.9	23.7	26.0	7.9	8.0	7.7
L-601	37.8	39.7	38.2	7.2	10.2	9.9
Tashkent-1	40.5	42.1	45.1	9.6	9.9	8.9

* - Plant developmental stages: 1 = squaring; 2 = flowering; 3 = boll-ripening

Table 2. Fiber quality of cotton inbred lines and commercial varieties.

Line or Variety	Cotton Fiber Quality Characteristics			
	Fineness,	Breakin g Strength	Breakin g Length	Staple length
	m/g (μg/m)	gms-force	km	mm (in)
L-3	4460 (224.2)	4.5	20.1	26.7 (1.05)
L-461	5010 (199.6)	4.3	21.8	35.5 (1.40)
L-501	5840 (171.2)	3.7	21.6	31.7 (1.25)
L-549	4640 (215.5)	3.7	17.2	26.2 (1.03)
L-601	6660 (150.2)	3.9	26.0	33.2 (1.31)
Tashkent-1	6440 (155.3)	4.0	25.8	33.0 (1.30)

Table 3. Correlation coefficients between photosynthetic traits and fiber properties in cotton.

Photosynthetic Traits	Cotton Fiber Characteristics					
	Fineness			Breaking Strength		
	1*	2	3	1	2	3
	------ meter/gram ------			------- gm-force -------		
Carbon Exchange Rate mg $CO_2/dm^2 h$	0.73	0.74	0.76	-0.81	-0.72	-0.65
Specific Leaf Weight g/dm^2	0.53	0.70	0.79	-0.80	-0.78	-0.69
Net Assimilation Rate $g/m^2 \cdot d$	0.67	0.63	0.57	-0.25	-0.12	-0.26
Leaf Area dm^2/plant	0.86	0.79	0.78	-0.43	-.046	-0.53
	Breaking Length			Staple Length		
	---------- km ----------			---------- mm ----------		
Carbon Exchange Rate mg $CO_2/dm^2 h$	0.42	0.48	0.50	0.49	0.50	0.64
Specific Leaf Weight g/dm^2	0.20	0.35	0.56	0.47	0.55	0.56
Net Assimilation Rate $g/m^2 \cdot d$	0.62	0.58	0.56	0.96	0.96	0.90
Leaf Area dm^2/plant	0.73	0.65	0.60	0.17	0.05	0.03

* - Plant developmental stages: 1 = squaring; 2 = flowering; 3 = boll-ripening

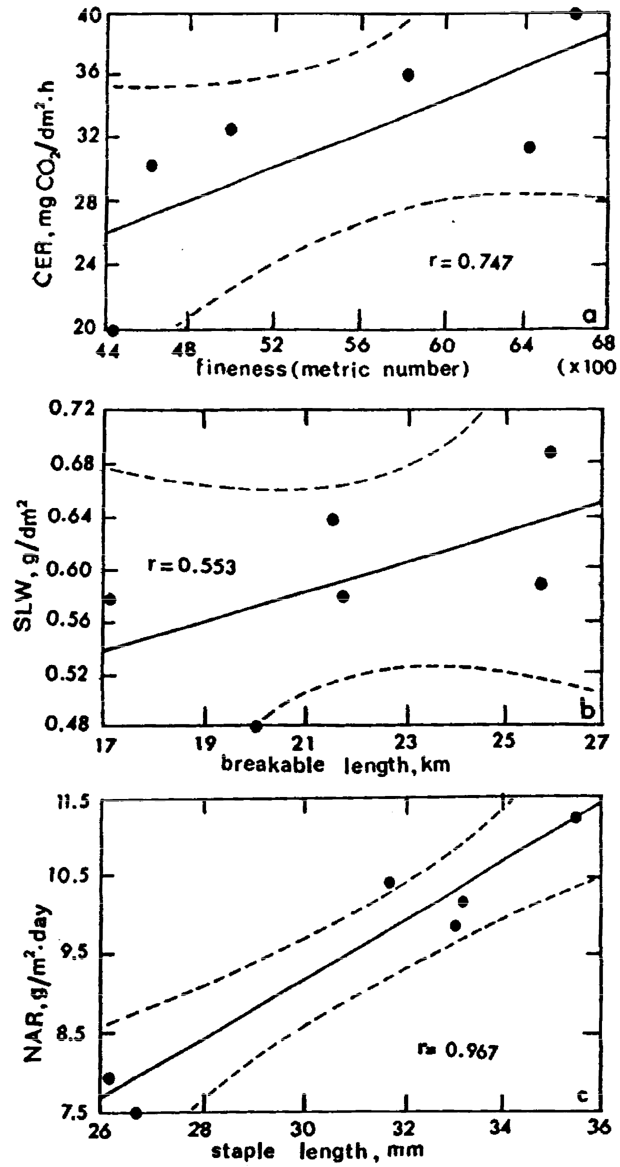

Figure 1. Dependence of cotton fiber quality on photosynthetic traits.