



Plant Production Science

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GENETIC VARIABILITY AND INTERRELATIONSHIPS AMONG EARLINESS CHARACTERS, YIELD-RELATED TRAITS AND FIBER QUALITY PARAMETERS IN CERTAIN COTTON GENOTYPES

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Received: 22/06/2021 ; Accepted: 01/08/2021

ABSTRACT: This study aimed at assessing genotypic variability among six cotton genotypes and their 15 F₁ crosses, clarifying the relationship between cotton yield and important agronomic traits, and determining the amount of direct and indirect impacts of attributed traits on cotton yield. Six long-staple and high-yielding cotton genotypes and their 15 F₁ crosses were evaluated in the summer season of 2017 at the Experimental Farm of Sids Research Station, Beni-Suef, Egypt. The obtained results revealed highly significant differences among parental genotypes and their F₁ crosses for all evaluated traits. The phenotypic coefficient of variation (PCV) was greater than the genotypic coefficient of variation (GCV) for all studied traits. The difference between PCV and GCV was very low for days to first flower unfolding, days to first opened boll, and uniformity ratio, while was relatively higher for number of nodes to first sympodial branch, lint index, micronaire reading, fiber strength, 100-seed weight, seed yield/plant, and lint yield/plant. The heritability in broad sense (h^2_b) values were high for days to first flower unfolding, days to first opened boll. Moreover, number of opened bolls/plant and boll weight/plant had positive and significant genotypic and phenotypic correlation with seed yield/plant and lint yield/plant. Furthermore, number of opened bolls/plant, boll weight/plant, and 100-seed weight exhibited positive direct effect on seed cotton yield. The highest indirect effects on seed cotton yield were assigned for number of opened bolls/plant, boll weight/plant, 100-seed weight, lint percentage, and lint index through lint yield/plant. The obtained results provide valuable information for cotton breeding programs to develop new high-yielding genotypes with acceptable fiber quality parameters.

Key words: Cotton, genetic variability, genotypic and phenotypic coefficients of variation, genotypic and phenotypic correlation coefficients and path analysis.

INTRODUCTION

Cotton (*Gossypium barbadense*) is an important crop worldwide and occupies a unique position in the agricultural system (Hu *et al.*, 2019). It is considered as a main source of foreign exchange earnings from exporting cotton materials (Ferris, 2011). Cotton not only meets fiber requirements but also seed oil extracted is used for human food and the remnants are used as raw material in feed mixtures (Bellaloui *et al.*, 2015). In Egypt, the cultivated area of cotton

declined from 2 million feddan in 1980 to 250 thousand feddan in 2020 (FAOSTAT, 2021). Consequently, great national efforts have been dedicated to increasing cotton production through breeding programs.

Cotton breeders work hardly through breeding programs to develop gene combinations and novel genotypes with high-yielding and acceptable fiber quality parameters. The first step to develop desired genotypes is assessing the genetic variability as well as examining the heritability

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of evaluated traits (Ashokkumar *et al.*, 2014). Moreover, the effectiveness of breeding programs is impacted considerably by magnitude of the relationship between final yield and attributed traits as well as the importance of each trait (Dao *et al.*, 2017). Path analysis is an effective statistical analysis to break down the relationships of attributed traits with final yield into their direct and indirect impacts (Janmohammadi *et al.*, 2014). Furthermore, genotypic and phenotypic correlations among yield traits could help through indirect selection by selecting easier measuring traits in breeding programs (Pordel-Maragheh, 2013).

The present study aimed at assessing the genotypic variability among six cotton genotypes and their 15 F₁ crosses (*Gossypium barbadense*, L.), clarifying the relationship between cotton yield and the other important agronomic traits and determining the amount of direct and indirect impacts of attributed traits on cotton yield.

MATERIAL AND METHODS

Breeding Materials and Field Experiments

Six long-staple and high-yielding cotton genotypes were crossed following half-diallel mating system (6×6) in the summer season of 2016. The used parents were two Egyptian commercial cultivars, two advanced lines (F₁₀), and two exotic genotypes (Table 1). The derived 15 F₁ hybrids and their six parents were sown in randomized complete blocks with three replications in the Experimental Farm of Sids Research Station, Beni-Suef, Egypt (29° 04' N, 31° 05' E) in the second season in 2017. The hybrids and their parents were sown April 4th in single plots included two ridges 4 m long with 80 cm spaces between ridges and 60 cm between hills. All recommended agricultural practices for cotton production were applied uniformly to minimize environmental variability.

Studied Traits

The number of nodes to first sympodial (fruiting) branch (NFSB) and days to first flower unfolding (DFFU) were counted from the sowing date. Days to first opened boll (DFOB) were counted from the sowing date. Number of

opened bolls/plant (NOB/P) was averaged at 150 days after sowing from 10 plants of each plot. Boll weight/plant (BW/P, g) was measured as the average of 10 bolls from each plot. Seed yield/plant (SCY/P, g) was measured as the average of the harvested lint plus the seed from 10 plants of each plot. Lint yield (LCY/P, g) was measured as the average of lint obtained from 10 plants of each plot, and 100-seed weight (100-SW, g) was measured as the weight of 100 seeds that were taken randomly from each plot. Lint percentage (L%) and lint index (LI) were calculated in accordance with the following equations:

$$L\% = \frac{\text{Lint yield (LCY/P)}}{\text{Seed yield (SCY/P)}} \times 100$$

$$LI = \frac{\text{Lint percentage (L\%)} \times 100 \text{ seed weight (100-SW)}}{100 - \text{Lint percentage (L\%)}} \times 100$$

Fiber properties were recorded in the laboratories of Cotton Technology Research Division, Cotton Research Institute, Agriculture Research Center, Egypt, following the standard method of the American Society for Testing Materials Designation (American Society for Testing Materials, 1998) at 21°C ± 1°C and 65% ± 2% relative humidity. Micronaire reading (MR) was used to express fiber fineness. Fiber strength (FS) was measured by using a Pressley instrument at zero gauge (g/tex). Fiber strength is closely related to yarn and fabric strength and spinning efficiency. Fiber length at 2.5% (FL, mm) was estimated as the space in mm spanned by 2.5% of the fibers as recorded on a digital fibrograph. Uniformity ratio (UR%) was calculated following the equation:

$$UR\% = \frac{50\% \text{ span length}}{2.5\% \text{ span length}} \times 100$$

Statistical Analysis

All traits were subjected to analysis of variance according to Steel *et al.* (1997). Genotypic variance (σ²_g), phenotypic variance (σ²_p), phenotypic coefficient of variation (PCV), and genotypic coefficient of variation (PCV) were estimated according to Burton and Devane (1953). Path analysis was calculated according to the revised method of Dewey and Lu (1959).

Table 1. Name, pedigree, and origin of the six cotton varieties used as parents for this study

Codes	Genotype	Pedigree	Origin
P1	Giza-90	Giza-83 x Dendra	Egypt
P2	Giza-95	(Giza-83 × [Giza-75 × 5844] × Giza-80)	Egypt
P3	Australian	Unknown	Australia
P4	C.B58	Unknown	USA
P5	PL10	Giza-90 × C.B58	Egypt
P6	PC10	([G83 × Giza-80] × Giza-89) × Australian	Egypt

RESULTS AND DISCUSSION

Genetic Variability

Analysis of variance for earliness traits, yield attributed traits and fiber quality parameters are presented in Table 2. The assessed genotypes displayed highly significant differences in all studied traits. Moreover, dividing the genotypic variance into parents and crosses revealed that the variance due to parental genotypes and their crosses were highly significant for all studied traits (Table 2). Obtained findings disclosed the presence of genetic variability in the used parental genotypes and their crosses. Consequently, the evaluated parents and their cross combinations could be exploited further in cotton breeding programs for improving earliness, yield traits, and fiber quality parameters. Likewise, earlier studies deduced significant variance between evaluated cotton parents and their cross combinations as **Khalifa et al. (2016)**, **Taha et al. (2018)**, **El-Aref et al. (2019)**, **Al-Hibbiny et al. (2020)** and **Geng et al. (2021)**.

The phenotypic (PCV) and genotypic (GCV) coefficients of variation values are shown in Table 3. The PCV was higher than GCV values in all investigated traits. Notwithstanding, the values of PCV and GCV differed slightly. The difference between PCV and GCV was very low for days to first flower unfolding, days to first opened boll, lint yield/plant and uniformity ratio (Table 3). This demonstrates slight environmental impacts on these traits. Nevertheless, the difference was relatively higher for number of nodes to first sympodial branch, lint index, micronaire reading, fiber strength, 100-seed weight, seed yield/plant, and lint yield/plant. The relatively

higher difference between PCV and GCV indicates to higher impact of the environment on the expression of these traits. Moreover, broad-sense heritability (h^2_b) values ranged from moderate to high values for assessed traits. The highest h^2_b values were assigned for days to first flower unfolding, days to first opened boll. High values of h^2_b for these traits suggest the majority of additive gene action in the inheritance of these traits and thereupon propose selection in early generations. These results are in line with that reported by **Abou El-Yazied et al. (2014)**, **Dhivya et al. (2014)**, **Ahsan et al. (2015)**, **Gnanasekaran et al. (2018)**, **Kumar et al. (2019)** and **Alishah (2021)**.

Genotypic and Phenotypic Correlation Coefficients

The genotypic and phenotypic correlation coefficients between earliness characters, yield-related traits, and fiber quality parameters are presented in Table 4. The results elucidated that number of opened bolls/plant and boll weight/plant had positive and significant genotypic and phenotypic correlation with seed yield/plant and lint yield/plant (Table 4). Furthermore, 100-seed weight displayed significant and positive correlation coefficients with lint index. Besides, micronaire reading showed positive and significant correlation coefficients with fiber strength. Additionally, fiber strength demonstrated positive and significant correlation coefficients with uniformity ratio. The obtained results proved the importance of these traits in improving cotton yield and fiber quality. Similar trends were manifested by **Punitha et al. (2013)**, **Pujer et al. (2014a)**, **Monisha (2018)**, **Bhatti et al. (2020)** and **Eldessouky et al. (2021)**.

Table 2. Mean squares of evaluated traits, namely, earliness traits, fiber quality, and yield and its contributing traits for the six cotton genotypes and their 15 F₁ crosses

Source of variation	df	NFSB	DFFU	DFOB	NOB/P	BW/P	SCY/P	LCY/P
Replication	2	0.26 ^{NS}	0.06 ^{NS}	0.14 ^{NS}	1.44 ^{NS}	0.01 ^{NS}	0.10 ^{NS}	0.11 ^{NS}
Genotypes	20	0.94 ^{**}	5.48 ^{**}	44.48 ^{**}	24.42 ^{**}	0.11 ^{**}	310.45 ^{**}	71.67 ^{**}
Parents (P)	5	0.67 ^{**}	16.90 ^{**}	47.53 ^{**}	23.14 ^{**}	0.15 ^{**}	183.35 ^{**}	61.98 ^{**}
Crosses (C)	14	0.68 ^{**}	1.66 ^{**}	38.52 ^{**}	26.61 ^{**}	0.06 ^{**}	276.13 ^{**}	52.11 ^{**}
Error	40	0.06	0.09	0.17	0.82	0.02	0.38	0.33
Total	62	0.35	1.83	14.46	8.45	0.04	100.39	23.34

Source of variation	df	L%	100-SW	LI	MR	FS	FL	UR
Replication	2	0.02 ^{NS}	0.05 ^{NS}	0.04 ^{NS}	0.02 ^{NS}	0.01 ^{NS}	0.34 ^{NS}	0.38 ^{NS}
Genotypes	20	1.98 ^{**}	1.49 ^{**}	0.77 ^{**}	0.11 ^{**}	0.21 ^{**}	1.80 ^{**}	3.23 ^{**}
Parents (P)	5	3.46 ^{**}	1.13 ^{**}	0.82 ^{**}	0.13 ^{**}	0.18 ^{**}	1.64 ^{**}	1.96 ^{**}
Crosses (C)	14	0.95 ^{**}	1.63 ^{**}	0.81 ^{**}	0.11 ^{**}	0.24 ^{**}	1.70 ^{**}	3.75 ^{**}
Error	40	0.15	0.06	0.04	0.01	0.02	0.15	0.33
Total	62	0.74	0.52	0.28	0.04	0.08	0.69	1.26

df is degrees of freedom, NS is not significant, * is significant at P-value < 0.05 and ** is highly significant at P-value < 0.01.

NFSB is number of nodes to first sympodial branch, DFFU is days to first flower unfolding, DFOB is days to first opened boll, NOB/P is number of opened bolls/plant, BW/P is boll weight/plant (g), SCY/P is seed yield/plant (g), LCY/P is lint yield/plant (g), L% is lint percentage, 100-SW is 100-seed weight (g), LI is lint index, MR is micronaire reading, FS is fiber strength (g/tex), FL is fiber length at 2.5% (mm) and UR is uniformity ratio (%).

Table 3. Breeding parameters for the studied traits in six cotton genotypes and their 15 F₁ crosses

Trait	σ^2_g	σ^2_p	GCV	PCV	h^2_b
Number of nodes to first sympodial branch	0.29	0.35	8.40	9.26	82.18
Days to first flower unfolding	1.80	1.89	2.13	2.18	95.31
Days to first opened boll	14.77	14.94	3.31	3.33	98.84
Number of opened bolls/plant	7.87	8.68	5.56	5.84	90.60
Boll weight/plant (g)	0.04	0.04	5.95	6.20	92.01
Seed yield/plant (g)	67.36	103.73	5.34	6.35	64.94
Lint yield/plant (g)	15.78	24.11	6.49	7.54	65.45
Lint percentage (%)	0.61	0.76	1.92	2.15	80.02
100-seed weight (g)	0.47	0.54	7.26	7.72	88.39
Lint index	0.24	0.28	7.62	8.20	86.28
Micronaire reading	0.03	0.04	4.48	5.01	79.91
Fiber strength (g/tex)	0.06	0.09	2.50	2.93	72.93
Fiber length at 2.5% (mm)	0.55	0.70	2.36	2.65	79.00
Uniformity ratio (%)	0.97	1.29	1.16	1.35	74.83

Table 4. Genotypic (r_g) and phenotypic (r_{ph}) correlation coefficients for the evaluated traits

Trait	Corr	NFSB	DFFU	DFOB	NOB/P	BW/P	SCY/P	LCY/P	L%	100-SW	LI	MR	FS	FL
DFFU	r_g	-0.17												
	r_{ph}	-0.14												
DFOB	r_g	0.41	0.25											
	r_{ph}	0.37	0.24											
NOB/P	r_g	-0.07	0.01	-0.20										
	r_{ph}	-0.11	-0.01	-0.19										
BW/P	r_g	-0.34	0.03	-0.21	-0.41									
	r_{ph}	-0.26	0.05	-0.20	-0.46									
SCY/P	r_g	-0.39	0.03	-0.41	0.49*	0.59**								
	r_{ph}	-0.35	0.03	-0.40	0.47*	0.57**								
LCY/P	r_g	-0.36	-0.07	-0.45	0.43*	0.62**	0.98**							
	r_{ph}	0.32	-0.06	-0.45	0.41	0.59**	0.97**							
L%	r_g	-0.11	-0.35	-0.43	0.04	0.49*	0.51*	0.68**						
	r_{ph}	-0.10	-0.30	-0.39	0.04	0.40	0.44*	0.65**						
100-SW	r_g	0.31	-0.08	0.05	0.21	-0.01	0.20	0.14	-0.12					
	r_{ph}	0.29	-0.07	0.06	0.17	0.00	0.18	0.13	-0.11					
LI	r_g	0.25	-0.22	-0.13	0.23	0.21	0.41	0.43*	0.31	0.91**				
	r_{ph}	0.23	-0.19	-0.11	0.19	0.18	0.37	0.41	0.34	0.90**				
MR	r_g	-0.12	-0.17	-0.45	0.05	0.03	0.09	0.06	-0.04	0.17	0.15			
	r_{ph}	-0.11	-0.16	-0.41	0.04	0.03	0.08	0.06	0.00	0.10	0.09			
FS	r_g	-0.16	0.00	-0.03	-0.09	-0.31	-0.38	-0.41	-0.35	-0.21	-0.35	0.61**		
	r_{ph}	-0.16	0.00	-0.04	-0.06	-0.27	-0.33	-0.33	-0.20	-0.20	-0.28	0.53**		
FL	r_g	-0.13	0.29	0.23	0.09	0.24	0.30	0.30	0.16	0.30	0.36	-0.38	-0.22	
	r_{ph}	-0.08	0.25	0.20	0.06	0.23	0.26	0.26	0.11	0.25	0.29	-0.30	-0.19	
UR	r_g	-0.33	0.00	-0.11	-0.30	0.18	-0.09	-0.12	-0.16	-0.32	-0.38	0.47	0.62**	-0.17
	r_{ph}	-0.24	0.00	-0.09	-0.22	0.13	-0.08	-0.09	-0.08	-0.31	-0.33	0.39	0.47*	-0.12

NFSB is number of nodes to first sympodial branch, DFFU is days to first flower unfolding, DFOB is days to first opened boll, NOB/P is number of opened bolls/plant, BW/P is boll weight/plant (g), SCY/P is seed yield/plant (g), LCY/P is lint yield/plant (g), L% is lint percentage, 100-SW is 100-seed weight (g), LI is lint index, MR is micronaire reading, FS is fiber strength (g/tex), FL is fiber length at 2.5% (mm) and UR is uniformity ratio (%).

Path Coefficient Analysis

Direct and indirect effects of yield attributed traits on seed cotton yield are presented in Tables 5. Number of opened bolls/plant, boll weight/plant, and 100-seed weight exhibited positive direct effect on seed cotton yield. Furthermore, the correlation coefficients between these traits and seed cotton yield were positive. This confirms the effectiveness of direct selection for these traits to achieving high cotton yield. The highest indirect effects on seed cotton yield were assigned for number of opened

bolls/plant, boll weight/plant, 100-seed weight, lint percentage, and lint index through lint yield/plant (Table 5). This indicates to the presence of true relationship between the aforementioned traits and seed cotton yield. The obtained results reveal that direct and indirect selection through these traits is very useful for developing high-yielding cotton genotypes. These results are in agreement with that reported by *Salahuddin et al. (2010)*, *Pujer et al. (2014b)*, *Jangid (2019)*, *Amein et al. (2020)*, *Chapepa et al. (2020)* and *Sarwar et al. (2021)*.

Table 5. Direct and indirect effect of yield traits on seed cotton yield/plant

Characters	NOBP	BW/P	LCY/P	L%	100-SW	LI	Correlation
NOBP	0.11	-0.06	0.43	-0.01	0.02	-0.03	0.47
BW/P	-0.05	0.12	0.61	-0.09	0.001	-0.03	0.57
LCY/P	0.04	0.07	1.04	-0.14	0.02	-0.07	0.97
L%	0.004	0.05	0.68	-0.22	-0.02	-0.05	0.44
100-SW	0.02	0.001	0.13	0.02	0.15	-0.14	0.18
LI	0.02	0.02	0.43	-0.07	0.13	-0.16	0.37

NOB/P is number of opened bolls/plant, BW/P is boll weight/plant (g), SCY/P is seed cotton yield/plant (g), LCY/P is lint cotton yield/plant (g), L% is lint percentage, 100-SW is 100 seed weight (g) and LI is lint index.

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التباين الوراثي والعلاقة المتبادلة بين صفات التبكير، صفات المحصول ومقاييس جودة الألياف في بعض التراكيب الوراثية من القطن

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تهدف هذه الدراسة إلى تقييم التباين الوراثي بين ستة تراكيب وراثية من القطن وخمسة عشر هجين في الجيل الأول، وكذلك دراسة العلاقة بين صفة محصول القطن والصفات المحصولية الهامة، وأيضاً تحديد مقدار التأثيرات المباشرة وغير المباشرة للصفات المحصولية على محصول القطن. تم تقييم ستة تراكيب وراثية من القطن طويلة التيلة وعالية المحصول وخمسة عشر هجين ناتج منها في الجيل الأول في صيف 2017 في المزرعة التجريبية لمحطة بحوث سدس بني سويف. أظهرت النتائج وجود فروق معنوية بين التراكيب الوراثية وهجن الجيل الأول لجميع الصفات التي تم تقييمها. وكان معامل التباين المظهري (PCV) أكبر من معامل التباين الوراثي (GCV) لجميع الصفات المدروسة. وكان الفرق بين PCV و GCV منخفضاً جداً لصفة عدد الأيام حتى تفتح أول زهرة، عدد الأيام حتى تفتح أول لوزة ومعدل الانتظام عند 2.5%. بينما كان الفرق عالي نسبياً لصفات عدد العقد حتى أول فرع ثمري، معامل الشعر، قراءة الميكرونير، قوة الألياف، وزن المئة بذرة، محصول القطن الزهر للنبات ومحصول القطن الشعر. وكانت قيم كفاءة التوريث في المعنى الواسع عالية لصفة عدد الأيام حتى تفتح أول زهرة وعدد الأيام حتى تفتح أول لوزة. علاوة على ذلك، أظهرت صفة عدد الأيام حتى تفتح أول لوزة ووزن اللوز على النبات ارتباط وراثي ومظهري موجب ومعنوي مع محصول القطن الزهر ومحصول قطن الشعر. وكذلك أظهرت صفة عدد اللوز المتفتح على النبات، وزن اللوز على النبات ووزن المئة بذرة تأثير إيجابي مباشر على محصول القطن الزهر. كذلك تم تحديد أعلى تأثيرات موجبة غير مباشرة على محصول القطن الزهر لعدد اللوز المتفتح على النبات، وزن اللوز على النبات، وزن المئة بذرة، نسبة التصافي ومعامل الشعر من خلال محصول القطن الشعر. توفر النتائج المتحصل عليها في هذه الدراسة معلومات مهمة لبرامج تربية القطن لتطوير تراكيب وراثية جديدة عالية المحصول ذات مقاييس جودة ألياف مقبولة.

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