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RESPONSE OF COTTON VARIETIES TO DIFFERENT ENVIRONMENTS: FLOWERING BEHAVIOR AND FIBER QUALITY

Dana Jawdat[1,*], Mouhammad Amir Hilali[2], Zouhair Ayyoubi[1], Rana Elias[1], Ridwan Al-Rayan[1], Mouhammad Nayef Al-Salti[2], and Bassam Al-Safadi[1]

[1]Department of Molecular Biology and Biotechnology, Atomic Energy Commission of Syria, Damascus, Syria;
[2]Cotton Research Administration, Al Midan square, Aleppo, Syria.
[*]Corresponding author's e.mail: ascientific@aec.org.sy

Flowering behavior and fiber quality traits were analyzed of six *Gossypium hirsutum* L. varieties and one *G. barbadense* variety that were cultivated in two environmentally different locations. Records of days after planting (DAP) at first floral bud emergence, DAP at first floral opening, plant height at first flower and nodes above white flower (NAWF) were analyzed statistically to study flowering behavior in both locations. Fiber traits were tested and records of micronaire, fiber length, strength, cohesion, elongation, ginning percentage, and weight of seed cotton were statistically analyzed to look for significant differences and correlations. Earliness and a decline in fiber strength, and fiber cohesion were obtained in varieties cultivated in Soujeh accompanied with an increase in ginning percentages. Uniquely, fiber elongation showed no significant differences in varieties between the two environments in both seasons. Our results indicated that stability in some fiber traits such as, micronaire, fiber length, strength and cohesion was a variety specific. Evidently, fiber elongation in our work was not affected by cultivation managements and environmental conditions which suggest the solid genetic bases that control this trait.
Keywords: *Gossypium* spp., flowering, fiber properties, environment.

INTRODUCTION

Cotton has marked its place as one of the most important crops in the world with an economic value resulting mostly (90%) from its natural fiber (Lubbers *et al*., 2007). Cotton seed oil is also of good value and cotton is ranked as the fifth oil-producing plant after soybean, palm-tree, colza and sunflower (Sawan *et al*., 1988 reviewed in Li *et al*., 2009). World annual yield production of seed cotton has increased from 0.86 t/ha in 1960-61 to 2.14 t/ha in 2006-07. Cotton fiber yields have also increased; where fiber output per hectare (world average) grew from 0.3 tons to 0.8 tons over the 1960-61 to 2006-07 (UNCTAD). Seed cotton production in Syria was around 3953 and 3983 Kg/Ha in 2008 and 2009, respectively.

The genus *Gossypium* has around 50 species including four species that have been domesticated for their fiber production. The popular *Gossypium hirsutum* among the four species is an allopolyploid ($2n$=$4x$=52; AD-genome) species that has originated from a single polyploidization event involving two diploid species; an A-genome maternal parent and a D-genome paternal parent approximately 0.5-2 mya (Cronn *et al*., 1999).

Most of the wild and primitive accessions of *G. hirsutum* are photoperiod sensitive and require short days to initiate flowering. Breeding programs were initiated in order to incorporate genes from day neutral (DN) *G. hirsutum* into some of these primitive accessions (McCarty *et al*., 1998) to enrich the genetic variation resources and produce new day neutral *G. hirsutum* accessions that are adaptable to long days growing seasons in the US and major cotton growing countries. Induced mutations were also applied to produce photoperiod-converted cotton mutant germplasm (Djaniqulov,1992 reviewed in Abdurakhmonov *et al*., 2007), which resulted in a number of commercial varieties such as AN-401, AN-402 and Kupaysin that are day-neutral cultivars with superior fiber qualities (Abudrakhmonov *et al*., 2007).

Allotetraploid *G. hirsutum* has a distinct growth manner in which the plant keeps a systematic morphological architecture (Khan, 2003) that can be useful in monitoring growth and developmental changes under diverse environmental conditions. It has been reported that vertical and horizontal flowering intervals in cotton are around 3 and 6 days respectively and it is still accepted even today (McClellan, 1916). Bednarz and Nichols (2005), and Godoy and Palomo (1999) reported that vertical flowering intervals are not affected during the selection process for early maturity. Horizontal flowering intervals, however, can be manipulated in breeding programs.

The quest for early maturity in cotton emerged as a result of the growers' fight against the cotton boll weevil, *Anthonomus grandis* Boheman (Buie, 1928). It has been noted by Al-Salti and Ibrahim (2001) and Al-Salti (2003) that the early cultivation of cotton and the use of early varieties have a clear impact in decreasing the level of cotton bollworms. Potential earliness in cotton varieties can contribute in successful crop rotation systems for countries producing both cotton and wheat for example such as the Syria. On the other hand, late maturation of cotton caused poor fiber characteristics such as staple length and fineness, and declined fiber strength (Salam *et al*., 1993). Earlier maturity can help in saving ground water for irrigation and can help, as well, in avoiding early rainfall that usually affects the harvest. Several morphological indices have been reported in literature to help estimate the cotton crop maturity and earliness such as: node of first fruiting branch, number of vegetative branches and the percentage of bolls on vegetative branches (Ray and Richmond, 1966); the time to first square or first flower (Joham, 1979).

Cotton is known to have an indeterminate growth habit subjected to many environmental and cultivation effects that can influence maturity. Maturity in cotton is accompanied by the slow development of the new main stem nodes. The number of nodes above first-positioned white flower relative to the plant apex was first reported by Waddle (1974) to indicate to the maturity status in cotton (Bourland *et al.*, 2001). It was observed that early maturing cultivars had fewer nodes above white flower (NAWF) during the third and fourth weeks of flowering than did the late maturing cultivars. Waddle suggested the potential use of NAWF counts as an indicator for cutouts and growth of any variety. It was then added that the sequential measurement of NAWF counts can be used as another parameter in monitoring maturity (Bourland *et al*., 1992).

The ultimate aim of cotton growers and cotton processors is to produce superior quality and quantity of fiber. The effect of environment on fiber development process is not fully understood and there have been several studies that identified some of the environmental factors, such as: optimal night temperature ranging between 15 to 21°C (Gibson and Joham, 1968), moisture deficits after flowering (Eaton and Ergle, 1952) and reduced sunlight conditions (Eaton and Ergle, 1954; Pettigrew, 1995) which affect the development of fiber. The current study aims at studying flowering behavior and fiber quality of local and introduced varieties of cotton under two different growth environments.

MATERIALS AND METHODS

Plant material**:** Plant material was consisted of seeds of five Syrian accredited local varieties of *Gossypium hirsutum* L.: Aleppo 118 (Aleppo 40 X American variety BW 76-31), Deir Al Zour 22 (a selected line from Delta Pine 41), Rakka 5 (a selected line from Tashkand 3), Aleppo 90 (Tashkand 3 X Delta pine 70) and Aleppo 33/1 (Acala SG 4) and one introduced variety Chirpan 539; along with one variety of *Gossypium barbadense* L. Russian C-6040.

Spatial and temporal cultivation**:** Cotton cultivation in Syria is allocated to certain areas that fulfill environmental requirements for growing specific adapted local cotton varieties under the supervision of the ministry of agriculture. One of the main areas for growing cotton in Syria is Aleppo country side, and hence Tal Hadyia area was selected in this study as a representative environment for growing adapted local varieties. Tal Hadyia is located north of Syria (36° 56′00″ E and 36° 01′ 57″ N) at 290 m above sea level. Soujeh area in Damascus country side is the second cultivation site in this study and is located in the south west of Syria (36° 04′ 09″ E and 33° 28′ 19″ N), around 300 Km far away from Tal Hadyia, at 1056 m above sea level.

Seeds were sown in rows at the end of April 2005 and 2007. Row to row and plant to plant cultivations within rows were kept at 75 and 25 cm respectively. Cultivation plots were designed according to a randomized complete block design (RCBD) with three replicates per variety.

The Soil in both cultivation sites was prepared by tractor ploughing deep for 45 cm, followed by two surface ploughing for 15 cm deep. Fertilization was conducted following the Cotton Research Administration (CRA) guidelines and recommendations that are specific for each cultivation region in the country. Nitrogen fertilizer (CH_4N_2O) was applied at a rate of 41.5 Kg/1000 m^2, where 20% of the total amount was applied during soil preparation, 40% was applied 30 days after sowing, 20% at floral buds emergence, and 20% at bolls initiation phase. Phosphorus fertilizer ($Ca(H_2PO4)_2$) was applied at a rate of 13 Kg/1000 m^2 during land preparation. Potassium fertilizer was applied in Soujeh cultivation area only at the rate of 17 Kg/1000 m^2 in the form of potassium sulphate based on soil chemical analysis, whereas, no potassium fertilizer was applied in Tal Hadyia due to the availability of endogenous potassium and according to CRA fertilization recommendations. Flood irrigation took place every 10 days at a rate of 40 m^3/1000 m^2. Thinning of plants was conducted around 4 weeks of germination.

Flowering behavior readings**:** Ten plants of each replicate were randomly tagged for recording data for days after planting (DAP) for first floral bud emergence, DAP for first floral opening, plant height at first flower, and nodes above white flower (NAWF).

Fiber quality testing**:** Thirty bolls of each replicate were picked and sent to the fiber quality lab at the CRA for testing: micronaire, fiber length, fiber strength, fiber cohesion, fiber elongation, and ginning percentage. CRA fiber quality lab conducts its testing according to the international testing standards with a temperature of 22°C ± 2°C and relative humidity of 64±4%. The lab uses the following instruments for Micronaire 775, the Digital Fibrograph, the Pressley tester and the Stelometer for fiber testing.

Meteorology**:** Each cultivation area under this study was covered by one meteorological station; METEO (METEO, Germany) in Soujeh area and CR10X measurement and control system (Campbell Scientific, USA) in Tal Hadyia. Meteorological readings considered for this study were: average temperature (°C), maximum and minimum temperatures (°C), solar radiation (MJ/M^2) and precipitation (mm).

Data analysis**:** STATISTICA (version 6.1) program (StatSoft, 2003) was applied to perform Analysis of Variance (ANOVA) at 0.05 significance level. STATVIEW (version 5) program (SAS, 1998) was used to run a t-test analysis and to calculate correlation and regression values at 0.05 significance level.

RESULTS

Flowering behavior**:** Meteorological data collected in both cultivation locations showed that maximum temperatures in Tal Hadyia were 4-5°C higher than Soujeh over the two years of study (2005 and 2007). Minimum temperatures were nearly similar in the two cultivation areas. The data also showed low rain fall in both locations, which in itself is not critical since cotton in Syria is an irrigated crop and cultivated off the main raining season. Solar radiation means of the period from day one of cultivation until anthesis day (SRCA) and solar radiation means of the period from day one of anthesis and 30 days after anthesis (SRA+30) were studied to compare the two locations in both growing seasons. SRCA means were around 10 mega joules/m^2 higher in Soujeh in 2005 than in Tal Hadyia. In 2007 the difference decreased to around 4 mega joules/m^2. SRA+30 means were around 3 and 4 mega joules/m^2 higher in Soujeh than Tal Hadyia in 2005 and 2007, respectively.

SRA+30 means were around 5 mega joules/m^2 higher than SRCA in 2005 and around 8 mega joules/m^2 in 2007 in Tal Hadyia cultivation area. A similar pattern was recorded in Soujeh cultivation area in 2007. However, in 2005 SRA+30 means were around 12 mega joules/m^2 lower than SRCA.

Statistical analysis showed low effect of average monthly temperature on plant age at first emerging square (floral bud) and plant age at first floral opening in both the locations, where regression factor (R^2) was 0.088 and 0.084 respectively. A positive correlation of 0.297 was found between average monthly temperature and plant age at first emerging square, whereas, a negative correlation of 0.290 was found between average monthly temperature and plant age at first floral opening.

SRCA in Tal Hadyia showed a relatively low to moderate effect ($R^2 = 0.35$) on emergence of first floral buds and a positive correlation value ($r = 0.592$); whereas in Soujeh the effect was higher ($R^2 = 0.74$) and higher positive correlation value ($r = 0.86$) than in Tal Hadyia.

A t-test at a confidence level of 95 % indicated that season and location showed a significant difference (P- Value < 0.05) on days after plantation at first floral bud phase. The varieties: Aleppo 90, Aleppo 33/1, and Russian C-6040 showed significant earliness in Soujeh in 2005 and 2007 compared to Tal Hadyia. Deir Al Zour 22 was the only variety that did not show any significant variation between locations in 2005 and 2007 (Table 1).

The earlier the floral buds emerge, the shorter the plants are at the floral opening phase. This was observed in each of Tal Hadyia and Soujeh cultivation locations, where the correlation values were 0.617 and 0.548 and R^2 values were 0.38 and 0.30 respectively. The data in Tal Hadyia showed a relatively high effect ($R^2 = 0.529$) of plant age at first floral bud on the period of time taken to open a flower and a high correlation factor value ($r = 0.727$). The effect was similarly high in Soujeh ($R^2 = 0.63$) along with a high correlation factor value ($r = 0.794$). The data in both locations showed that the later the first floral bud emerges, the shorter period it takes the bud to open.

NAWF counts for third week of flowering were recorded for all varieties, in both locations, over the two years of study (Table 2). A t-test analysis showed that both season and location gave significant differences in all varieties (P-value <0.001). NAWF counts were significantly lower in Soujeh compared to Tal Hadyia for each variety in 2005 (Table 2). However, in 2007 only Chirpan 539 (an early flowering variety) kept its NAWF count pattern between the two locations. No significant differences between the two locations were observed in NAWF counts of the other varieties in 2007.

Fiber properties**:** Running a t-test analysis indicated that there was no significant difference between the two cultivation seasons and the two cultivation sites in fiber micronaire. Data also showed that there was no significant difference between locations in fiber length and weight of seed cotton, and that no significant difference between seasons in both fiber cohesion and elongation. The difference between the two seasons in ginning percentage was highly significant (P-value <0.001). Significant difference (P-value <0.01) was recorded between the two seasons in fiber length and between the two cultivation sites in fiber strength and ginning percentage. Fiber strength and weight of seed cotton showed significant difference (P-value < 0.05) between seasons. Whereas, a significant difference (P-Value < 0.05) in both fiber cohesion and elongation was observed between the two locations.

Seven fiber traits were analyzed using ANOVA, and variance partition sources were analyzed according to year, location, and year X location.

Varieties showed no significant differences in micronaire between seasons and between locations. Aleppo 33/1 was unique in producing fibers with no significant differences in micronaire in both seasons and locations (Table 3). Variation in fiber length was observed in most varieties between locations except for Aleppo 118 variety, which showed no significant difference between the two locations in each season.

Table 1. Mean values of days after plantation at first floral bud phase in Tal Hadyia and Soujeh cultivation locations over the two years of study

Genotype	Year		location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 45.62	A 45.26	A 49.73	B 42.40	A 51.65	B 40.40	C 46.40	C 44.63
Aleppo 90	A 52.74	B 44.60	A 51.91	B 47.50	A 54.29	B 51.13	C 47.00	D 43.16
Aleppo 33/1	A 50.41	B 41.95	A 51.09	B 43.57	A 52.76	B 48.13	B 47.87	C 39.00
Rakka 5	A 50.00	B 43.72	A 49.31	B 46.00	A 49.60	A 50.40	A 48.73	B 40.72
Deir Al Zour 22	A 49.13	B 44.83	A 48.44	A 46.51	A 49.70	A 48.57	B 45.93	B 44.22
Chirpan 539	A 43.95	B 38.63	A 42.62	A 41.03	A 43.73	A 44.17	B 40.40	C 37.68
Russian C-6040	A 45.90	B 42.24	A 49.57	B 41.45	A 47.60	B 44.20	A 49.33	C 38.70

Numbers in rows sharing a letter in each block (Year, location, and Year X location) are not significantly different. Data were subjected to ANOVA (General Linear Model) and Duncan's test with a confidence level of 95 % using STATISTCA program.

Table 2. Mean values of NAWF counts in Tal Hadyia and Soujeh cultivation locations over the two years of study

Genotype	Year		Location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 5.57	B 2.91	A 4.83	B 4.08	A 6.04	B 5.17	C 2.73	C 3.00
Aleppo 90	A 4.90	B 3.27	A 5.09	B 3.53	A 6.10	B 3.70	C 3.07	C 3.37
Aleppo 33/1	A 5.30	B 3.11	A 5.00	B 3.88	A 6.00	B 4.63	C 3.07	C 3.13
Rakka 5	A 5.12	B 2.98	A 4.55	B 3.93	A 5.47	B 4.77	C 2.73	C 3.10
Deir Al Zour 22	A 4.80	B 3.04	A 5.15	B 3.22	A 6.20	B 3.40	B 3.07	B 3.03
Chirpan 539	A 3.97	B 2.93	A 4.35	B 2.90	A 4.83	BC 3.10	C 3.40	B 2.70
Russian C-6040	A 5.10	B 3.38	A 5.69	B 3.37	A 7.07	BC 3.13	B 2.93	C 3.60

Numbers in rows sharing a letter in each block (Year, location, and Year X location) are not significantly different. Data were subjected to ANOVA (General Linear Model) and Duncan's test with a confidence level of 95 % using STATISTCA program.

Table 3. Mean values of fiber traits in Tal Hadyia and Soujeh cultivation locations over the three years of study Micronaire

Genotype	Year		Location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 4.77	A 4.82	A 4.91	A 4.67	A 4.67	AB 4.87	B 5.15	A 4.48
Aleppo 90	A 4.37	A 4.28	A 4.34	A 4.31	A 4.13	B 4.60	B 4.55	A 4.02
Aleppo 33/1	A 4.40	A 4.51	A 4.46	A 4.45	A 4.37	A 4.43	A 4.55	A 4.47
Rakka 5	A 4.31	A 4.42	A 4.51	A 4.21	A 4.25	A 4.37	B 4.78	A 4.05
Deir Al Zour 22	A 4.47	A 4.55	A 4.68	A 4.34	A 4.40	AB 4.55	B 4.97	A 4.13
Chirpan 539	A 4.83	A 4.83	A 4.92	A 4.75	AB 4.73	AB 4.93	B 5.10	AB 4.57
Russian C-6040	A 4.32	A 4.42	A 4.21	A 4.53	AB 4.25	AB 4.38	A 4.16	B 4.68

Fiber length (Fibrograph)

Genotype	Year		Location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 1135.50	B 1177.17	A 1153.00	A 1159.67	A 1134.00	A 1137.00	B 1172.00	B 1182.33
Aleppo 90	A 1099.17	B 1147.00	A 1110.67	A 1135.50	A 1117.67	B 1080.67	AB 1103.67	C 1190.33
Aleppo 33/1	A 1144.67	B 1201.83	A 1181.67	A 1164.83	A 1181.67	B 1107.67	A 1181.67	B 1222.00
Rakka 5	A 1130.83	B 1169.50	A 1134.17	A 1166.17	A 1104.33	B 1157.33	B 1164.00	B 1175.00
Deir Al Zour 22	A 1095.00	B 1144.67	A 1104.17	A 1135.50	A 1080.67	B 1109.33	B 1127.67	C 1161.67
Chirpan 539	A 1128.00	A 1109.67	A 1099.67	A 1138.00	A 1116.00	A 1140.00	B 1083.33	A 1136.00
Russian C-6040	A 1177.33	B 1216.83	A 1207.00	A 1187.17	A 1198.67	B 1156.00	A 1215.33	A 1218.33

Table 3 cont…

Fiber strength (Pressley)

Genotype	Year		location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 9.52	A 9.04	A 9.67	B 8.88	A 10.05	B 8.98	B 9.29	B 8.80
Aleppo 90	A 8.64	A 8.72	A 8.88	A 8.47	A 8.78	A 8.50	A 8.99	A 8.45
Aleppo 33/1	A 9.76	A 9.67	A 10.36	B 9.08	A 10.42	B 9.11	A 10.30	B 9.04
Rakka 5	A 8.58	A 8.25	A 8.59	A 8.25	A 8.25	A 8.92	A 8.93	B 7.58
Deir Al Zour 22	A 8.81	A 8.65	A 9.05	B 8.41	A 9.06	A 8.57	A 9.04	A 8.26
Chirpan 539	A 8.63	A 8.34	A 8.81	B 8.16	A 8.65	A 8.61	A 8.98	B 7.71
Russian C-6040	A 8.97	A 8.84	A 9.14	A 8.66	A 9.10	A 8.84	A 9.19	A 8.49

Fiber cohesion (stelometer)

Genotype	Year		location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 24.23	A 24.41	A 25.53	B 23.10	A 25.91	BC 22.54	AC 25.15	C 23.67
Aleppo 90	A 22.37	A 22.49	A 22.83	A 22.03	A 23.10	A 21.64	A 22.56	A 22.42
Aleppo 33/1	A 27.52	A 26.60	A 28.88	B 25.24	A 29.97	B 25.08	C 27.80	B 25.41
Rakka 5	A 22.68	A 22.50	A 22.74	A 22.43	A 22.02	A 23.33	A 23.46	A 21.53
Deir Al Zour 22	A 22.04	A 22.46	A 22.72	A 21.78	A 22.55	A 21.53	A 22.90	A 22.02
Chirpan 539	A 21.57	A 21.29	A 21.92	A 20.94	A 22.11	A 21.02	A 21.72	A 20.87
Russian C-6040	A 26.14	A 25.73	A 27.72	B 24.15	A 28.93	B 23.36	C 26.52	B 24.95

Fiber elongation (Stelometer)

Genotype	Year		location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 5.10	A 5.00	A 4.85	A 5.25	A 5.00	A 5.20	A 4.70	A 5.30
Aleppo 90	A 4.90	A 5.02	A 4.78	A 5.13	A 4.77	A 5.03	A 4.80	A 5.23
Aleppo 33/1	A 5.03	A 4.85	A 4.52	A 5.37	A 4.47	A 5.60	A 4.56	A 5.13
Rakka 5	A 6.75	A 5.92	A 6.40	A 6.27	A 7.20	AB 6.30	B 5.60	AB 6.23
Deir Al Zour 22	A 4.78	A 5.62	A 4.97	A 5.43	A 4.63	A 4.93	A 5.30	A 5.93
Chirpan 539	A 5.02	A 4.95	A 4.77	A 5.20	A 4.97	A 5.07	A 4.57	A 5.33
Russian C-6040	A 7.12	A 6.32	A 6.70	A 6.73	A 7.27	A 6.97	A 6.13	A 6.50

Ginning (%)

Genotype	Year		location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 40.58	A 39.87	A 38.94	B 41.51	A 39.02	B 42.14	A 38.86	AB 40.88
Aleppo 90	A 41.50	B 38.80	A 39.18	A 41.12	A 39.38	B 43.63	A 38.97	A 38.61
Aleppo 33/1	A 41.55	B 38.80	A 38.99	B 41.92	A 39.32	B 43.77	A 38.65	A 40.07
Rakka 5	A 41.88	B 39.24	A 39.77	A 41.35	A 40.46	B 43.31	A 39.08	A 39.40
Deir Al Zour 22	A 43.33	A 41.87	A 42.47	A 42.71	A 43.92	AB 42.74	B 41.03	B 42.68
Chirpan 539	A 39.72	A 38.14	A 37.82	B 40.05	A 37.85	B 41.60	A 37.79	A 38.49
Russian C-6040	A 39.75	A 38.06	A 37.11	B 40.69	A 37.30	B 42.19	A 36.93	A 39.20

Weight of seed cotton (g)

Genotype	Year		location		Year X Location			
	2005	2007	Tal Hadyia	Soujeh	Tal Hadyia 2005	Soujeh 2005	Tal Hadyia 2007	Soujeh 2007
Aleppo 118	A 188.17	A 205.00	A 193.67	A 199.50	AB 194.33	B 182.00	AB 193.00	A 217.00
Aleppo 90	A 160.50	A 176.83	A 173.00	A 164.33	AB 174.33	B 146.67	AB 171.67	A 182.00
Aleppo 33/1	A 184.83	A 193.00	A 192.33	A 185.50	A 198.33	A 171.33	A 186.33	A 199.67
Rakka 5	A 169.67	A 190.67	A 172.67	A 187.67	A 171.33	A 168.00	A 174.00	B 207.33
Deir Al Zour 22	A 140.67	B 165.17	A 154.83	A 151.00	A 143.33	A 138.00	A 166.33	A 164.00
Chirpan 539	A 147.67	A 162.83	A 154.67	A 155.83	A 145.33	A 150.00	A 164.00	A 161.67
Russian C-6040	A 91.67	B 138.00	A 109.33	A 120.33	A 93.33	A 90.00	B 125.33	B 150.67

Numbers in rows sharing a letter in each block (Year, location, and Year X location) are not significantly different. Data were subjected to ANOVA (General Linear Model) and Duncan's test with a confidence level of 95 % using STATISTCA program.

Data showed a general drop in fiber strength in Soujeh compared to Tal Hadyia. Three varieties (Aleppo 90, Deir Al Zour 22, and Russian C60-40) produced fibers with no significant difference in strength between locations in both seasons (Table 3). A decrease in fiber cohesion was also observed in varieties cultivated in Soujeh compared to Tal Hadyia. However, four varieties (Aleppo 90, Rakka 5, Deir Al Zour 22, and Chirpan 539) showed no significant differences between locations in both seasons. Data showed a considerably high positive correlation value between fiber strength and cohesion where r value is 0.697 and 0.729 in Tal Hadyia and Soujeh respectively. Cohesion was found to be positively correlated with fiber length with an (r) value of 0.731 and 0.582 in Tal Hadyia and Soujeh, respectively.

Fiber elongation recorded no significant differences between locations in both seasons for all varieties except for Rakka 5 which produced less fiber elongation in Tal Hadyia in 2007 compared to 2005 (Table 3). Fiber elongation and micronaire were found to be negatively correlated, where r values of 0.43 0.33 were obtained in Tal Hadyia and Soujeh, respectively.

Ginning percentage was affected by seasons and locations. Ginning percentage increased significantly in Soujeh in 2005, while in 2007 a little increase in ginning percentage in most varieties cultivated in Soujeh was recorded (Table 3). The weight of seed cotton showed no significant difference in all varieties between the two locations in each season, except for Rakka 5 in 2007 (Table 3).

DISCUSSION

Flowering behavior and fiber quality were tested in seven cotton varieties cultivated in two different environments for two seasons. Soujeh cultivation site is located around 1056 m above sea level and recorded lower maximum temperatures and higher SRCA means than Tal Hadyia (290 m above sea level).

Average monthly temperature showed low effect on timing of first emerging square and timing of first opened flower, where the correlation factor values were around 0.3 in both locations. Maximum temperatures were considered among other climatic factors such as evaporation, sunshine duration, humidity, and surface soil temperature at 1800 h to be the most significant factors affecting flower and boll production of the Egyptian cotton (Sawan *et al*., 2002).

The SRCA means showed high effect on emergence of first floral buds, where the correlation values were 0.592 and 0.86 in Tal Hadyia and Soujeh respectively. The SRCA means in Soujeh were higher than in Tal Hadyia, which may explain the general earliness in Soujeh compared to Tal Hadyia. Therefore, it can be suggested that the significant earliness in Soujeh can be triggered by the low maximum temperatures and high SRCA means solely or jointly by other environmental and cultivation factors.

It was noted in our experiment that the earlier the floral buds emerge the shorter the plants are, which may indicate a slower vegetative development processes in favor for reproduction development of a plant. Several studies on floral bud removal have demonstrated that reproductive sink removal enhanced cotton plant vegetative growth and development through increased plant height and increased nodal development and branching (Bednarz and Roberts, 2001; Ungar *et al*., 1987). Additionally, a study on the removal of early season flower buds led to an increase in the taproot growth and vegetative shoot component (Sadras, 1996). Therefore, it can be suggested that the early emergence of floral buds slows down, to some extent, the vegetative growth of cotton plants and that there can be other endogenous or environmental factors jointly or separately affecting slower vegetative growth at flowering.

The current study showed that the late emergence of first floral buds was highly correlated with shorter period of time to open the first flower in both locations. Blooming usually occurs in cotton at the culmination of the square period and a flower opens when the cotton reproductive system has reached maturity. This may indicate an endogenous timing of bloom (floral opening) that is dependent on cotton reproductive maturity phase and less dependent on floral stimulus initiation phase during which squares are initiated and reproductive growth begins.

NAWF counts for third week of blooming showed, in the current work, the vulnerability of some varieties to different environments. NAWF counts of 5 signify the physiological cutout or the cessation of effective flowering phase (Bourland *et al.*, 2001). Physiological cutout can be used as a reliable measurement of accumulated effects of environmental and cultivation factors on crop development that occur before flowering of the last effective boll population (Bourland *et al.*, 2001) and hence determining earliness and maturity. Bourland and his group (2001) showed that physiological cutout did not include the influence of any late-season factors. NAWF counts have also been used to test early maturity of advanced *G. hirsutum* cultivars in Pakistan and found that during the third week of flowering certain cultivars (advanced strains) developed less than 5-NAWF counts suggesting that they ceased to grow further by the end of the third week and reached maturity one week earlier than the standard variety (Anjum *et al*., 2001). The current study showed seasonal and location variation and in NAWF counts. It can be suggested that environmental and possible cultivation factors had their effect on the cultivated varieties leading to different maturity behavior. The results endorse that NAWF counts, as an indicator of earliness, can be variety specific under specific environmental and cultivation conditions.

It has been stated that fiber traits are a product of three main factors: genetics, environment and management (Silvertooth, 2001). The current work acquired all measures for unifying management practices in both locations, which reflects the genetic and environment influences on fiber traits quality.

The fiber micronaire, reflects fiber fineness and has a desired value range in the international market between 3.5 and 4.9. Discounts apply on micronaires outside the range, with heavy discounts on micronaires less than 3.5. Micronaire is a measure of internal fiber thickness and deposits of cellulose. It has been reported that cotton varieties in the state of Arizona have the tendencies to produce higher micronaire across locations and that only 20% of that variation is due to genetics (Silvertooth, 2001). It has also been reported that one of the management practices that can impact cotton yield and fiber micronaire is the timing of the final irrigation; at the end of first fruiting cycle when NAWF counts are 5 or less (Silvertooth, 2001). Moisture deficit was reported to produce a high percentage of position 1 bolls on the sympodial branch and this was coupled with increase in fiber strength and micronaire (Pettigrew, 1995). The present study showed that locally bred variety Aleppo 33/1 had no significant differences between locations and seasons with an average micronaire of 4.46, suggesting its potency in breeding programs for varieties with stable micronaires.

Fibers are single elongated cells that extend from the seed coat during bolls development. Fiber elongation starts on the day of anthesis and lasts for 20 to 30 days and is considered a unique system for studying the mechanism of cell elongation (Ruan *et al*., 2001). It has been stated that far-red (FR) to red (R) photon ratio in reflected light received by field cotton plants influenced number of bolls and yield per plant (Kasperbauer, 1994). The same study suggested a possible effect of FR/R ratio on fiber length. Kasperbauer in 2000 found that fibers in unshielded bolls that developed over green and red soil covers (higher reflected FR/R) were significantly longer than those developed over aluminum and white (higher reflected photosynthetic photon flux). Heat-unit accumulation was reported to be associated with variations in fiber length (Quisenberry and Kohel, 1975). Fiber length can be affected by other environmental conditions such as soil moisture deficits which led to shorter fibers (Pettigrew, 2004). Severe water deficits during fiber elongation stage reduced fiber length (Hearn, 1994), which is directly related to cell expansion processes. However, the present study exposed the *G. hirsutum* variety Aleppo 118 to have no significant difference in fiber length between locations in both seasons. The other varieties showed, in this work , variation between locations and therefore, influenced by the environmental factors that govern the two cultivation sites.

Fiber strength or the inherent breaking strength of individual cotton fibers is the most important industrial factor that determines the strength of the yarn spun (Bradow and Davidonis, 2000). As mentioned earlier, an increase in fiber strength is coupled with a high percentage of position 1 bolls on the sympodial branch under moisture deficit (Pettigrew, 1995). It has been reported that fiber strength is significantly and positively correlated with mean growth temperature (Hanson *et al*., 1956). Fiber strength is suggested to be more responsive to the growth environment than are fiber length and fineness (Bradow and Davidson, 2000). However, fiber strength was found to be correlated closely and negatively with yield when environment conditions were not included in the experimental design, which means a stronger fiber costs a cotton plant its fiber weight and fiber number (Smith and Coyle, 1997). The present study showed a decrease in fiber strength in all the varieties grown in Soujeh, which had 4-5ºC lower maximum temperatures. However, two *G. hirsutum* varieties, Aleppo 90 and Deir Al Zour 22 and the Russian C-6040 *G. barbadense*, showed no significant variation in response to location and cultivation seasons. This, in turn, signified their potential in breeding for fiber strength.

Fiber cohesion is an important fiber property for processing and spinning and is what holds fibers together for processing (Foulk *et al*., 2007). It was reported that correlations of yarn strength to fiber strength, fiber cohesion and fiber regularity are important (Bogdan, 1956). Fiber cohesion depends on the fiber surface properties such as, wax, pectin and metal content. It also depends on insect contamination, fiber-to-fiber friction, fiber length and electrostatic potential (Foulk *et al*., 2007). Our study showed a positive correlation of fiber cohesion with fiber length and fiber strength. It has been reported that pectin is negatively correlated with fiber friction (Gamble, 2003), and that exposing cotton during normal ginning processes to temperatures can degrade sugars and pectin which could in turn affect fiber processing (Foulk *et al*., 2007). Therefore, investigating factors affecting fiber surface properties and the analysis of the latter can be a good indicator of fiber cohesion and ultimately fiber processing and spinning.

Fiber elongation is found to be determined by additive genetic effects along with fiber finenesss (Ali *et al*., 2008), which was in agreement with the results Ahmad *et al*. (2003) and Basal and Turgut (2005). These fiber characteristics can be improved via selection (Ali *et al*., 2008). It has been suggested that the genetic expression of elongation is more independent of environmental conditions than it is for fiber strength (Ethridge and Boman, 2009). This is consistent with our results where the data showed no significant differences between the two environments, which reflected the sable genetic factor(s) concerning fiber elongation. It has been found that about 73% of the total variation in yarn elongation can be a result from variations in fiber elongation and it was recommended that elongation should receive a considerable attention in plant breeding programs (Ethridge and Boman, 2009).

Ginning percentage is affected by environmental stresses such as water stress and it has been found that non-stressed plants ginned out 2.7 to 3.7% higher than plants subjected to mid-bloom water stress which was attributed to delays in maturity caused by the water stress (Osborne *et al.*, 2006). Ginning percentage was found to be negatively correlated with fiber length and fiber strength (Kardemir *et al.*, 2010). The results of our study agreed with those of Kardemir *et al.* (2010), who observed a negative low correlation of ginning percentage with fiber length and fiber strength.

The improvement of cotton varieties with high yield and optimum fiber properties is what cotton breeders and industry are seeking. Varieties examined in this study provided an interesting genetic background material for advanced molecular studies on flowering time in cotton and quantitative trait loci (QTL) influencing flowering and fiber quality, in particular the fiber elongation.

***Conclusions*:** The significant earliness in Soujeh can be triggered by the low maximum temperatures and high SRCA means solely or jointly by other environmental and cultivation factors. Our work has indicated to a possible endogenous timing of bloom (floral opening) that is dependent on cotton reproductive maturity phase and less dependent on floral stimulus initiation phase during which squares are initiated and reproductive growth begins. It is also endorsed that NAWF counts, an indicator of earliness, can be variety specific under specific environmental and cultivation conditions.

Variation in fiber traits was described as a response to different environments, where some traits decreased such as, fiber strength and fiber cohesion and the others such as fiber elongation showed stability in different environments in both seasons. Some varieties showed stability in certain traits between locations in both seasons. such as, Aleppo 33/1 in micronaire; Aleppo 118 in fiber length; Aleppo 90 and Deir Al Zour 22 in fiber strength and cohesion; Russian C-6040 in fiber strength; Rakka 5 and Chirpan 539 in fiber cohesion. These varieties are potential candidates in breeding programs that can be supported with marker assisted selection to ensure best parents.

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