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Responses of cotton-cultivars to long day conditions

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Abstract. Flowering of cultivated varieties of cotton belonging to *G. arboreum*, *G. herbaceum* and *G. hirsutum* was delayed by over 14 hrs of daylength because of increase in number of days for square formation. The long day treatment in general increased height, production of fruiting branches, leaf area and dry weight per plant. The number of fruiting forms, bolls retained, yield of seed cotton and fruiting coefficient decreased under long day conditions. These characters were affected more in upland varieties and short day Cambodia derivatives. The most of *G. arboreum* and *G. herbaceum* varieties became more vegetative in growth but their boll number and yield per plant increased.

Since the varieties 1998 F (*G. hirsutum*) and Gaorani 1111 (*G. arboreum*) were tolerant to long photoperiod and grew satisfactorily, it is suggested that these may be used as donor parents for improving the quality of cottons grown in northern India.

Keywords. Photoperiod ; flowering ; long day ; boll ; square ; yield.

1. Introduction

The flowering of cultivated and wild species of cotton is governed by both daylength and temperature as shown by Waddle *et al* (1961) and Mauney and Phillips (1963). They found that most of the varieties flower under short days and cool nights. The importance of low night temperature in promoting flowering was further stressed by Mauney (1966) using a non-photoperiodic upland cotton variety. Bhatt (1977) and Bhatt *et al* (1976) found that long days and high temperature singly or in combination delayed flowering of upland cottons of northern India whereas the photosensitive Cambodia varieties did not flower under long days alone or long day plus high temperature. The upland genotypes when grown at latitudes 29° N, 21° and 11° N flowered progressively earlier and at lower nodes at more southern latitudes because of reduction in daylength and temperature.

Though the cotton crops in the northern cotton zone in India are grown under irrigation and thus give higher yields, they are of short and medium staple. An attempt was therefore made to screen some of the promising varieties (belonging to both *G. hirsutum* and *G. arboreum*) for tolerance to long days so as to identify donor parents for improving quality.

2. Materials and methods

The cultivated varieties in India representing three species of cotton and an F_1 hybrid developed through genetic male sterile line were taken as shown below :

Species	*Variety*	*Area*
G. hirsutum	LSS	Upland type from North zone
G. hirsutum	320 F	Upland type from North zone
G. hirsutum	CP 1998 F	Grown in South zone
G. hirsutum	170 Co 2	An Indo-American type grown in Central zone
G. hirsutum	MCU 1	Photosensitive short day derivative of Cambodia cotton from South (used as check)
G. arboreum	AK 235	From Central zone
G. arboreum	G 27	From North zone
G. arboreum	K 9	From South zone
G. arboreum	Gaorani 1111	From South zone
G. arboreum	Gaorani 1187	From South zone
G. herbaceum	V 797	Grown in Central zone
G. herbaceum	Jayadhar	Grown in South zone
	CPH 2	An intraspecific (*G. hirsutum*) hybrid

The cotton varieties were raised in large (45 cm diameter and 105 cm depth) pots adequately manured. There were six plants per treatment one in each pot. The daylength around latitude 30°N in northern cotton zone in India when cotton is sown and even thereafter until about 80 days is over 14 hours. The normal daylength in summer at Coimbatore (latitude 11° N) varies from 11·50 hrs to 12·20 hrs. It was extended to 14·50 hrs through 60 watt incandescent lamps. The treatments were (i) Control, *i.e.*, normal daylength of 11·50 hrs to 12·20 hrs, and (ii) long photoperiod of 14·50 hrs. Under both the treatments the day and night temperatures were the same. The day temperature was between 34·0° C to 35·5° C from germination to square formation for about 35 days and thereafter until flowering did not rise above 36·8° C. The night temperature during this period fluctuated between 17·5° C to 21·8° C to 24·6° C and subsequently remained around 23·0° C. The long day treatment was discontinued after 75 days after sowing. Taking cotyledonary node as zero, the node on the main stem producing first sympodium was taken as the first fruiting node. The fruiting coefficient is defined as the yield of seed cotton produced per 100 gm of total dry matter (Crowther 1944).

3. Results

The long days delayed formation of flower buds in all the varieties irrespective of the species (table 1). The short day Cambodia derivatives MCU 1 and 170 Co 2 set squares just after the long day treatment was discontinued. The early types CPH 2 and 1998 F took only 4 and 6 days more respectively to square when compared with the delay of three weeks in LSS and 320 F. Among the diploids both the Gaorani types were early whereas in the rest, delay in square formation ranged from 15 to 20 days.

Most of the varieties took significantly more days to flower when photoperiod was extended except CPH 2 and 1998 F with a delay of 4 and 9 days respectively and of 6 days in Gaorani 1111. With a difference of only 2 days Gaorani 1187 appeared to be practically photoinsensitive. The photosensitive types MCU 1 and 170 Co 2 took maximum days to flower followed by the upland types LSS and 320 F, and the Asiatic type AK 235. The square period, *i.e.*, the number of days from initiation of flower bud to opening of the flower remained more or less the same between the treatments except that it increased by 3 days in 1998 F and reduced by 3 days in G 27, 5 days in K 9, 6 days in Gaorani 1187 and 3 days in Jayadhar.

Table 1. Flowering behaviour of cotton-cultivars as affected by extended photoperiod.

Species	Variety	Number of days to square		Number of days to flower		First fruiting node		Days for first boll bursting	
		C	T	C	T	C	T	C	T
G. hirsutum	LSS	34	56	52	75	4·3	9·0	118	150
G. hirsutum	320 F	33	54	56	75	4·0	6·0	120	145
G. hirsutum	CP 1998 F	25	31	46	55	4·0	6·0	85	95
G. hirsutum	170 Co 2	35	72	54	89	3·0	7·6	120	147
G. hirsutum	CPH 2	22	26	42	46	6·0	6·0	86	84
G. hirsutum	MCU 1	39	73	59	95	2·3	10·3	110	130
G. arboreum	AK 235	33	52	53	72	3·0	7·0	122	140
G. arboreum	G 27	35	50	55	67	5·3	7·7	118	130
G. arboreum	K 9	34	54	59	74	2·6	7·0	125	142
G. arboreum	Gaorani 1111	35	42	53	59	2·0	6·6	130	139
G. arboreum	Gaorani 1187	35	43	53	55	4·6	7·7	125	132
G. herbaceum	V 797	45	60	65	82	5·0	6·0	130	150
G. herbaceum	Jayadhar	35	50	65	77	2·6	5·0	120	135
S.E. for varieties			1·90		8·61		1·40		4·84
S.E. for treatment			1·10		3·51		0·58		1·97

C = Control T = Treatment

The node at which the first sympodial branch appeared was also higher, the notable exceptions being CPH 2 and V 797. Other varieties flowered 2–8 nodes higher under long day conditions.

An increase in daylength also increased boll maturation period, *i.e.*, the days from opening of the first flower to dehiscence of carpellary wall or boll bursting thus adding to further lateness. The trend was more or less similar to flowering. The upland type LSS took the maximum number of days whereas CPH 2 was unaffected. It was interesting to note that the Gaorani cultures 1187, 1111 and 1998 F were late by 7, 9 and 10 days respectively.

Except for CPH 2 and Gaorani 1111 plant height increased significantly in all the varieties reaching the maximum in 170 Co 2 and LSS (table 2). The number of sympodia per plant also increased similarly except in CPH 2, V 797 and CP 1998 F. The long day conditions reduced production of fruiting forms with notable exceptions of G 27 and K 9 showing an increase whereas CP 1998 F was not affected significantly. Maximum reduction was found in MCU 1, AK 235 and V 797.

There was a significant increase in leaf area per plant in all the varieties. It was over three times in LSS and over twice the normal area in 320 F, MCU 1 and G 27 followed by 170 Co 2. Increase in leaf area was comparatively less in CPH 2, V 797 and CP 1998 F.

Table 2. Effect of extended photoperiod on some growth characters.

Species	Variety	Height (cm)		No. of sympodia per plant		No. of fruiting forms per plant		Leaf area per plant (cm^2)	
		C	T	C	T	C	T	C	T
G. hirsutum	LSS	60·2	117·1	12	20	41·6	30·7	2983	11581
G. hirsutum	320 F	65·3	95·2	9	15	33·3	39·0	2950	6170
G. hirsutum	CP 1998 F	40·3	60·8	13	14	42·0	39·0	2507	3575
G. hirsutum	170 Co 2	55·3	120·7	12	22	34·2	22·6	4210	8179
G. hirsutum	CPH2	54·1	54·3	11	12	38·0	30·0	2668	3548
G. hirsutum	MCU 1	51·3	90·1	12	17	35·6	17·0	6170	13217
G. arboreum	AK 235	97·3	144·2	22	32	59·6	38·7	2850	4879
G. arboreum	G 27	108·0	130·8	19	25	65·6	70·0	2217	4717
G. arboreum	K 9	72·3	143·6	17	25	59·3	73·3	2980	5316
G. arboreum	Gaorani 1111	72·6	77·0	16	18	51·3	35·0	2950	4850
G. arboreum	Gaorani 1187	52·0	85·1	11	15	49·0	31·0	2170	3950
G. herbaceum	V 797	56·0	83·3	12	15	62·3	40·1	2007	2970
G. herbaceum	Jayadhar	59·1	101·2	14	20	54·3	41·6	2350	4317
S.E. for varieties			7·39		4·28		8·61		159·80
S.E. for treatments			3·02		1·75		3·51		65·24

C = Control T = treatment

At maturity dry matter per plant increased in most of the varieties under long day treatment (table 3). But CP 1998 F, AK 235 and Gaorani 1187 were not affected. It was, however, highly significant in CPH 2, LSS 320 F, MCU 1, K 9, Gaorani 1111 and Jayadhar.

In *G. hirsutum* varieties LSS 170 Co 2 and MCU 1, the number of bolls per plant at maturity decreased with consequent decrease in yield of seed cotton. Both 320 F and CP 1998 F were unaffected whereas CPH 2 recorded higher yield under long days. Except Gaorani 1187, all *G. arboreum* varieties and V 797 had more number of bolls and yielded more. Jayadhar remained unaffected. Fruiting coefficient of most of the varieties decreased because of higher dry weights of their vegetative parts when grown under long days.

4. Discussion

The enhanced photoperiod delayed flowering because of increase in the number of days required to initiate square formation. The square period was more or less unaffected in *G. hirsutum* varieties confirming the previous findings of Bhatt (1977). *G. arboreum* varieties were similarly affected except Gaorani cultures where flowering was delayed by 2 and 6 days only. The *G. arboreum* variety used by Mauney and Phillips (1963) showed essentially no reaction to the environments in their study whereas flowering was delayed from 12 to 19 days under long day conditions in the present study with the first fruiting node pushed up significantly. Differences in flowering responses of different varieties reported by Mauney and Phillips (1963) and in our experiments may be attributed to differences in day and night temperatures though long day conditions were similar. Day temperatures in their experiments varied from 27° C to 32° C whereas the night temperature was fixed at 15° C or 30° C, while in our experiments day temperatures varied from 34° C to 36° C and night temperatures from 17° C to 24° C.

An increase in leaf and stem dry weight and a decrease in yields of seed cotton of most of the varieties under long days reduced their fruiting coefficients (Bhatt 1970). In *G. hirsutum* group CP 1998 F responded exceptionally well in terms of its vegetative and reproductive growth maintaining high fruiting coefficient. This variety was late in flowering by 9 days under extended photoperiod and took 95 days for the first formed boll to burst as against 150 and 145 days taken by the northern upland varieties LSS and 320 F respectively. Because of its superior fibre characters, better yielding capacity and high degree of tolerance to long day conditions, it may prove as a suitable donor parent for improving the quality of northern *hirsutums* in India. Next in performance was the intra-*hirsutum* hybrid CPH 2. But the short day Cambodia derivatives MCU 1 and 170 Co 2 failed miserably in relation to flowering and growth (Hutchinson 1959; Bhatt 1977).

The *G. arboreum* varieties except Gaorani 1111 took 12 to 19 days more to flower and their bolling period also increased by 12 to 18 days. The new culture Gaorani 1111 in this respect took only 6 to 9 days more for flowering and boll bursting respectively. It compares well with the northern *arboreum* variety G 27 in terms of yield of seed cotton and similar fruiting coefficient. By virtue of its long staple, it may prove useful for improving the quality of northern *arboreums* in India.

Table 3. Effect of extended photoperiod on yield characters.

Species	Variety	Dry weight per plant (gm)		No. of bolls per plant		Yield of seed cotton per plant (gm)		Weight of lint (gm)		Fruiting coefficient	
		C	T	C	T	C	T	C	T	C	T
G. hirsutum	LSS	170·8	243·9	14·3	5·2	42·1	19·3	13·8	6·3	0·24	0·08
G. hirsutum	320 F	142·4	203·6	9·0	10·0	37·3	35·0	12·3	11·5	0·26	0·17
G. hirsutum	CP 1998 F	79·3	80·7	16·0	17·0	49·0	49·0	17·1	17·1	0·61	0·60
G. hirsutum	170 Co 2	196·4	211·9	10·0	6·0	39·7	24·1	13·9	8·4	0·20	0·11
G. hirsutum	CPH 2	62·6	112·7	10·0	14·0	32·8	55·2	11·5	19·3	0·52	0·49
G. hirsutum	MCU 1	195·9	261·0	11·6	8·0	40·1	29·7	13·2	9·8	0·20	0·11
G. arboreum	AK 235	199·9	198·8	5·6	9·1	10·2	15·3	3·4	5·2	0·08	0·07
G. arboreum	G 27	197·2	204·2	20·0	24·3	36·0	43·2	11·8	14·2	0·18	0·20
G. arboreum	K 9	178·3	222·1	13·6	23·0	26·1	45·0	8·6	14·8	0·14	0·20
G. arboreum	Gaorani 1111	142·5	203·3	12·6	21·6	23·0	38·1	7·6	12·6	0·16	0·18
G. arboreum	Gaorani 1187	172·3	169·8	17·7	9·6	30·7	15·3	10·1	5·0	0·17	0·09
G. herbaceum	V 797	135·7	175·4	7·0	18·0	13·8	25·0	5·0	9·0	0·10	0·14
G. herbaceum	Jayadhar	115·0	164·3	16·6	15·6	32·3	28·1	11·6	10·1	0·28	0·17
S.E. for varieties			38·76		6·59		10·47				
S.E. for treatment			15·82		69·2		4·27				

C = Control T = Treatment

Among the *G. herbaceum* varieties, V 797 though late in flowering and boll bursting appeared tolerant to longer photoperiod as its growth and yield improved. But the fruiting efficiency of Jayadhar was reduced markedly.

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