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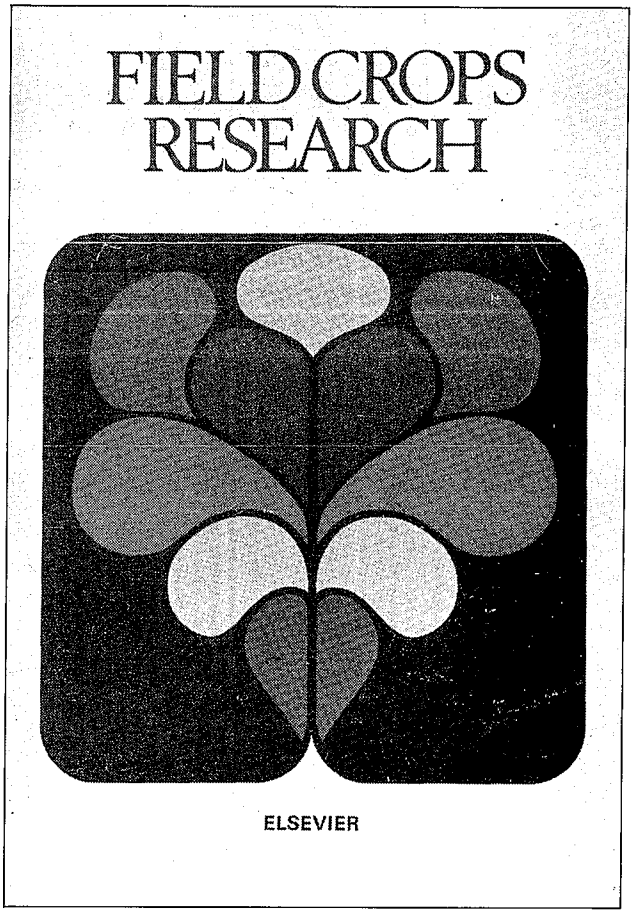

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EFFECT AND INTERACTION OF PHOTOPERIOD, TEMPERATURE, WATER STRESS AND NITROGEN ON FLOWERING AND GROWTH IN JUTE

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ABSTRACT

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The effect of environmental factors other than photoperiod on flowering in jute has not been adequately documented. Such knowledge is necessary if control over the flowering process is to be attained. Thus a factorial experiment was conducted in which the main effects and interactions of three genotypes, three day/night temperature regimes, three photoperiods, two levels of water supply and two nitrogen levels were studied. The experiment was conducted in three compartments of a glasshouse in which temperature was manipulated by evaporative coolers and gas-fired heaters and daylength by artificial lighting and light-proof compartments.

Photoperiod was the dominant factor controlling flowering, and hence growth habit. There was relatively little effect of temperature on flowering even though night temperatures below 20°C markedly delayed emergence and initial growth. Water stress applied during 35—40 days after germination delayed flowering but nitrogen treatment had no effect. Treatment effects on days to flowering were generally directly proportional to effects on yield parameters.

The present results suggest that occasional instances of premature flowering in jute, even though daylength during growth had been adequate, cannot be explained by temperature effects. Thus effects of light intensity or quality may be involved. Further, it is suggested that screening of genotypes for optimum flowering requirements (long vegetative period) may be done on the basis of photoperiod response alone, due to the relatively small effects of other environmental factors on flowering.

INTRODUCTION

A major determinant of fibre yield in jute is time of flowering, as the onset of flowering induces branching of the upper main stem and hence cessation of main stem elongation. Jute exhibits short-day flowering behaviour with critical daylengths generally being about 12 h for *Corchorus capsularis* varieties and 12½ h for *C. olitorius* (Sen Gupta and Sen, 1946;

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Kundu et al., 1959). Thus jute growth for fibre production is limited to that part of the year with daylengths exceeding the critical daylength; viz. mid-April to August for *C. olitorius* in Bangladesh. Attempts to overcome this limitation have been made by screening for jute genotypes with lower critical daylengths and such genotypes have been identified (e.g. Kasem Ali, 1961; Mahtabuddin, 1976; Husain, 1977; Joseph and Saha, 1978).

However, if the flowering process in jute is to be adequately manipulated, either genetically or agronomically, then any effect of environmental factors additional to photoperiod on flowering must also be known. For example, for other species it is known that temperature (Wilsie, 1962; Huxley et al., 1976; Blondon et al., 1977), water stress (Guttridge, 1969) and mineral nutrition (Hillman, 1962) interact with the photoinduction of flowering. For jute it has been found that the time to flowering shortens with an increase in temperature, particularly night temperature (Bose, 1974, 1976). This finding is relevant to understanding the flowering response of jute sown early in the season, under short daylength and low temperatures, and deserves further investigation.

Even when daylangth exceeds the critical level throughout growth, instances of premature flowering in jute have been recorded in Bangladesh. This suggests an effect on flowering additional to simply that of photoperiod but the actual cause is yet to be identified. Thus there is a need to differentiate between the possible effects of different environmental factors on flowering.

An experiment was therefore conducted in which the main effects and interactions of a factorial combination of photoperiod, temperature, water supply and nitrogen treatments on three genotypes of jute with contrasting flowering responses were measured.

MATERIALS AND METHODS

Treatments were as follows:

(1) Genotype: (a) *Corchorus capsularis* cv. D-154; (b) *Corchorus capsularis* cv. CVE-3; (c) *Corchorus olitorius* cv. CG.

(2) Photoperiod: (a) 11¼-h daylength; (b) 12-h daylength; (c) 12¾-h daylength.

(3) Temperature: (a) 35—40°C day/20—25°C minimum (T_1); (b) 30—35°C day/20—25°C minimum (T_2); (c) 30—35°C day/15—20°C minimum (T_3).

(4) Water supply: (a) at field capacity throughout; (b) drought cycles at 35—40 days.

(5) Nitrogen: (a) 3 × 315 mg N/pot; (b) 1 × 125 mg N/pot.

Design was complete factorial with three replications. Treatments 1, 2, 4 and 5 were randomized in three blocks in each of three glasshouse compartments which were set at the designated temperatures.

Plants were grown in an organic matter—soil potting mixture in clay

pots 23 cm high and with 20 cm top diameter. Prior to sowing the following mineral nutrients were applied to the soil surface of pots and mixed to a depth of 3 cm:

(a) either 315 or 125 mg N per pot as NH_4NO_3 in solution (according to treatment 5);

(b) 315 mg P per pot as triple superphosphate in granules;

(c) 160 mg K per pot as KCl in solution;

(d) 8 mg Zn per pot as $ZnSO_4 \cdot 7H_2O$ in solution.

The conversion factor used (surface area basis) was 3.14 mg per pot = 1 kg per ha. The same amounts of K and P were reapplied at 50 and 51 days from sowing, respectively. A further 315 mg N was applied to the high nitrogen treatment pots at 32 and 52 days.

Seeds were sown in pots on 14 January 1980 and seedlings gradually thinned to five plants per pot by 31 days from sowing. Throughout the experiment plants were regularly sprayed for protection against red mite (*Tetranychus bioculatus*) and jute stem weevil (*Apion corchori*).

Photoperiod treatments were imposed by extending glasshouse daylength after sunset to 12¾ h using white fluorescent tubes and 100 W incandescent globes and placing pots at 11¼- and 12-h photoperiod treatments under light-proof covers for the required periods. Pots with shorter daylength treatments were taken from blocks and placed within wooden frames, which were draped with black plastic sheeting at the required time. After completion of the 12¾-h daylength, lights were switched off and plastic covers removed. Pots were returned to their randomly assigned positions in blocks each following morning. Photoperiod treatments continued for the duration of the experiment.

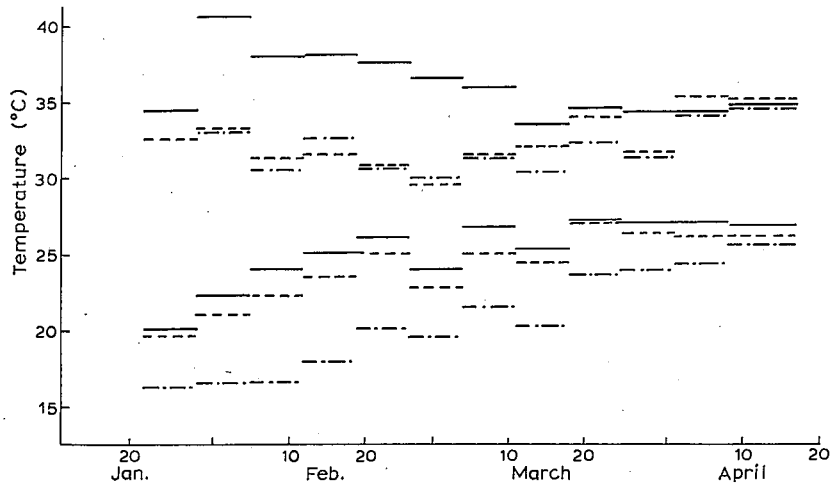

Fig. 1. Weekly averages of daily minimum temperatures and daily average temperature between 10.00 and 16.00 h for T_1 (——), T_2 (- - -) and T_3 (—— · ——) treatments in 1980.

Temperature treatments were imposed by appropriate adjustment of evaporative coolers and gas-fired heaters in three compartments of equal size in a glasshouse. Being a glasshouse, rigorous control of temperature could not be achieved but the required temperature differentials could be maintained until about mid-March (Fig. 1). Thereafter the increasing ambient minimum and day temperatures limited maintenance of differentials.

Two conditions of water supply were imposed as follows:

(a) One half of the pots were maintained at field capacity throughout the experiment (pots had through drainage).

(b) For the other half, wilting cycles were imposed during 35—40 days from sowing. Water was withheld until plant tips drooped and then sufficient water applied to restore turgidity. This cycle was repeated throughout the 5-day period. At all other times these pots were maintained at field capacity.

Temperatures were recorded thermographically throughout the experiment, apart from during the first week. Fig. 1 shows the temperature record, indicating the weekly averages of daily minimum temperature and average day temperature between 10.00 and 16.00 h. This latter depiction was preferred over daily maximums as these were usually achieved for short periods only, when electricity supply and thus coolers failed.

Humidity remained similar in each compartment. Daily values for relative humidity at 09.00 averaged 63 ± 11 (standard deviation), 60 ± 10 and 60 ± 12% for treatments T_1, T_2 and T_3 respectively. Relative humidities at 09.00 rose gradually from 55—60% in January and February to 65—70% in April.

Time of blooming of the first flower was recorded for each plant. Plant height was also measured on several occasions during growth. Plants were harvested at 93 days from sowing and green (fresh) weight, plant height, technical height (height to bifurcation of main stem induced by flowering) and base diameter recorded. Stems were then retted for 2 weeks, the fibre extracted and over dry weights of fibre and stick measured.

RESULTS

The initial increase in plant height was significantly reduced by low night temperature for each genotype (Table 1). Seedling emergence, particularly that for 'CG', was delayed at T_3. Plant height of 'CG' at early growth stages was also lower than for the *C. capsularis* varieties at T_1 and T_2 (Table 1). Immediately after cessation of the drought treatment, plant height of droughted plants, as a percentage of the control, was 88% for 'D-154', 87% for 'CVE-3' and 77% for 'CG'. No response of plant height to nitrogen treatment was recorded during growth.

Days from sowing to flowering were determined according to several criteria:

(a) time to flowering of the first plant in a pot;

(b) time for all plants in a pot to have flowered (final);
(c) average time for flowering of first three plants.

None of the plants at the 12¾-h photoperiod had flowered by the final harvest and so this photoperiod was excluded from the analysis of variance for flowering. For those treatments at shorter photoperiods where no flowering occurred, flowering time was considered to be 93 days (the harvest time) for the purposes of analysis.

The significant main effects and interactions of treatments on each of

TABLE 1

Effect of temperature treatment on plant height (cm) of three jute genotypes at 30 days from sowing

Genotype	Temperature treatment		
	T_1	T_2	T_3
'D-154'	37	33	19
'CVE-3'	39	35	19
'CG'	27	26	10

Least significant difference ($P = 0.05$) between any two means = 6.

TABLE 2

Statistical significance of main effects and interactions of treatments on flowering and yield parameters in jute

Source of error	Days to flowering			Yield parameter					
	First plant	All plants	Mean of three plants	Green weight	Stick weight	Fibre weight	Plant height	Technical height	Base diameter
Temperature (T)		***	**	***		***	***	***	***
Photoperiod (P)	***	***	***			***	***	***	*
T × P			*			**		*	
Genotype (G)	***	***	***	***	***	***	***	***	***
T × G		*			**	**			*
P × G	***	***	***	**	**	***	***	***	**
T × P × G			*				*	*	
Water (W)	***	*	***	***	***	***	***	***	
P × W						**	**	**	
G × W	*					**			
T × G × W									
P × G × W							*	*	
Nitrogen (N)			*			*	*	*	
P × N			*						
Replication	*	*	*	***	***	***	***	***	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

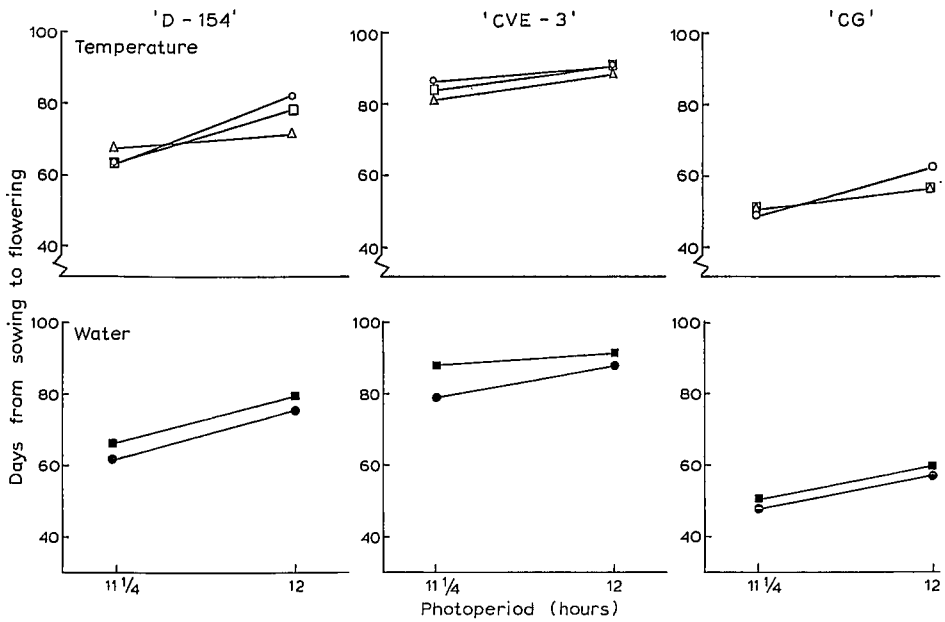

Fig. 2. Effect and interaction of temperature treatment and photoperiod and of water treatment and photoperiod on days from sowing to flowering (mean of flowering of first three plants in a pot) of three jute genotypes. Treatments: (○) = T_1; (□) = T_2; (△) = T_3; (◒) = field capacity throughout; (◘) = drought cycles at 35–40 days.

the criteria for days to flowering are shown in Table 2. The strongest effects were of photoperiod and genotype and their interaction. The effect of temperature on flowering and its interaction with other factors was relatively small. This is illustrated in Fig. 2 which shows that low night temperature (T_3) slightly decreases the number of days to flowering in 'CVE-3' and in 'D-154' at the 12-h photoperiod.

Drought stress during 35—40 days significantly delayed flowering in each genotype, with only minor, probably chance, interactions with other factors (Table 2, Fig. 2). There was no significant main effect of nitrogen treatment on flowering.

The effect of photoperiod treatments on yield parameters was generally directly proportional to the number of days to flowering (Tables 2 and 3). In this case data for the 12¾-h photoperiod treatment were included in the statistical analysis. The major effect of photoperiod was on plant height and fibre weight, rather than green weight or stick weight. Temperature effects were relatively greater for growth than flowering. Green weight, fibre weight, plant height and technical height were generally better at the T_3 treatment. The effects of the drought stress imposed at 35—40 days persisted until the final harvest as all yield parameters except base diameter showed highly significant effects (Table 2). In contrast to its effect on flowering, nitrogen treatment had a slight effect on some yield parameters (Table 2).

TABLE 3

Effect of temperature and photoperiod on yield parameters of three jute genotypes

Yield parameter	Photo-period (h)	'D-154'			'CVE-3'			'CG'		
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Green weight (g/plant)	11¼	50	44	45	53	48	57	30	28	35
	12	49	44	50	54	49	61	33	28	34
	12¾	46	44	54	52	49	54	40	35	45
Stick weight (g/plant)	11¼	23.5	18.8	19.1	20.5	23.5	25.3	13.8	12.2	14.4
	12	20.7	21.8	18.0	21.8	22.8	25.4	14.0	11.8	15.7
	12¾	20.6	20.8	20.8	18.5	22.2	22.6	16.1	17.2	19.7
Fibre weight (g/plant)	11¼	8.2	7.7	6.2	9.9	10.1	12.1	3.7	4.7	4.5
	12	8.2	9.1	7.7	10.8	11.2	13.8	5.9	4.3	5.7
	12¾	9.9	10.2	11.9	9.9	11.6	14.0	8.1	8.6	11.7
Plant height (cm)	11¼	147	141	166	155	153	182	109	114	111
	12	143	149	157	159	161	188	115	105	126
	12¾	151	151	179	160	158	172	150	147	175
Technical height (cm)	11¼	98	92	110	128	120	150	63	67	69
	12	115	112	110	143	137	172	72	65	76
	12¾	143	145	177	150	152	170	149	142	175
Base diameter (mm)	11¼	10.5	10.4	11.8	11.7	11.8	12.2	8.4	8.7	8.6
	12	11.2	11.6	12.3	12.1	12.5	12.8	8.4	8.5	8.2
	12¾	11.5	11.3	13.5	11.5	11.4	12.2	8.4	8.5	9.3

There were highly significant replication effects for all yield parameters, except base diameter (Table 2). This may have resulted from placement effects in each glasshouse compartment. For example, it was observed that blocks placed nearest the glass which partitioned compartments suffered most from red mite attack. There were also probably differential placement effects of light and temperature in each compartment. Red mite attack was most severe in the T_2 compartment, particularly at later growth stages, possibly contributing to the lesser growth in this compartment.

DISCUSSION

Of the factors studied, photoperiod had the largest effect on flowering. This effect was eventually reflected in plant height, technical height and fibre weight, as expected. A significant effect would also have been expected for stick weight, as this should correlate with technical height, but this was not obtained. However, the lack of effect of photoperiod treatment on green weight is consistent with inclusion of all branches and leaves in this measurement. The large differences between these genotypes in their responses of flowering and growth to photoperiod is evidenced by the highly significant photoperiod × genotype interactions obtained (Table 2).

The relatively small effects of temperature, as compared with photoperiod, on flowering contrast with other short day plants in which low temperature enhances flowering (Wilsie, 1962). The low night temperatures of this study only slightly enhanced flowering in *C. capsularis* varieties. Perhaps greater effects of temperature would have been obtained over a wider temperature range. However, in this study it was only intended to cover the range of temperatures likely to be found in Bangladesh from February to the monsoon period. In contrast to the above, flowering of soyabean (*Glycine max* cv. TK5) is enhanced by about 10 days by increasing the night temperature from 19 to 24°C (Huxley et al., 1976). This effect was larger than that of photoperiod (11 h 40 min vs 13 h 20 min) or day temperature (27 vs 33°C). Similarly, for both *C. olitorius* and *C. capsularis*, Bose (1974, 1976) found that time to flowering was shortened by about 20 days by day/night temperatures of 32/27, 27/27, 24/24°C, as compared to when night temperature was 17°C. However, in this study flowering was obtained under a 9-h photoperiod, far shorter than jute experiences under natural conditions (c.f. the shortest official daylength in Bangladesh of about 10½ h). Resolution of these differing results for jute will require detailed study using controlled environment facilities set to photoperiods encompassing the range 10½—12½ h.

Effects of temperature on plant growth per se seemed to be greater than on flowering response. Low night temperatures markedly delayed growth at early stages but, after minimum temperatures had reached 20°C, growth in T_3 caught up with and, by the final harvest, surpassed growth at T_1 and T_2. As to whether this is due to adverse effects of minimum temperatures above 25°C in T_1 and T_2 (e.g. causing excess respiratory loss) or less mite damage in T_3 is not known.

The effect of water stress in delaying flowering in jute has also been observed in other experiments where drought treatment was more severe (M. Waseque, unpubl. data, 1982). It is often found that mild water stress enhances flowering (Guttridge, 1969), although in cereals a transient water shortage appears to suspend the early stages of inflorescence development (Milthorpe and Moorby, 1979). Such a suspension also may be the case in jute as the delay in time to flowering caused by water stress in the present study is similar to the time over which the stress was applied (viz. 5 days).

For other species, it is often found that nitrogen application prolongs the vegetative phase (Hillman, 1962) although severe N deficiency may delay flowering (e.g. cotton; Malik et al., 1978). However, no effect of N on flowering was observed in this study. This may have been because sufficient N for maximum early growth was present in the low-nitrogen treatment. Thus the effect of N on flowering in jute needs to be tested under conditions of a growth response to N.

The relatively small effects of temperature, drought and N on flowering of jute in this study suggest that these factors are not involved in the premature flowering of jute sometimes observed when daylength is above the

critical level. Thus other explanations need to be sought. As instances of premature flowering are usually coincident with extended periods of overcast weather it is suggested that effects of light intensity and quality are implicated.

The present results suggest screening of jute genotypes for optimum flowering requirements, that is with a vegetative period of at least 100 days, may be done on the basis of photoperiod response alone, due to the relatively small effects of other environmental factors. However, with isolation of genotypes able to remain vegetative at photoperiods of less than 12 h, their ability to grow at low temperatures would then become a limiting factor to growth during periods of shorter daylength (e.g. February). This is indicated by the lesser growth when minimum temperatures were below 20°C (Table 1; Bose 1974, 1976).

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