STUDIES ON THE PHYSIOLOGY OF RICE

VIII. The Effects of Low and High Temperature Germination with or without Short Days on Summer and Winter Varieties

by S. M. Sircar, *F.N.I. and* B. N. Ghosh,* *Department of Botany, Calcutta University*

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Introduction

The effects of different temperatures and photoperiods on the flowering of summer and winter varieties of rice grown in the tropics have been reviewed elsewhere (Sircar, 1948). The results indicate marked differences in their behaviour towards the temperature of germination and day length. Thus by short day treatment of a winter variety, *Rupsail*, Sircar and Parija (1948) showed an acceleration of flowering from 133 to 47 days, a period known to be the shortest for winter rice to flower. This effect noticed only in the primary axis and the first and second tillers showing varying degree of earliness, appeared to be of varietal difference and localised in the shoot apices of the treated seedlings. Both low and high temperatures are without any vernalising effect in this variety. On the other hand, acceleration of flowering by high temperature and low temperature retardation led Ghosh (1949) to suggest that high temperature is an essential feature for the initiation of the reproductive phase in summer varieties. The short day effect in them is, however, to retard flowering or even to annul the effect of high temperature. In view of these contrasting behaviours the present investigation was undertaken to examine more critically the effects of low and high temperatures with or without short days on growth, flowering and yield of the two main crops of rice. In this paper the effects of such treatments are also discussed in the light of recent views on the physiology of flowering.

Materials and Methods

Summer Rice.—The effects of high temperature alone and in combination with short days were studied in 1946 with two summer varieties, *Charnock* and *Panbira*. Seeds graded and sterilised, were imbibed in water to 30 per cent of fresh weight in order to sprout the embryos without radicles and plumules emerging out of the seed coat (Sircar and Ghosh, 1947). The sprouted unsplit seeds were then vernalised at 35°C. for 10 and 20 days, and sown along with the respective control in earthenware seedbed pans on April 6 and 16. One week old seedlings of three seedbeds were then exposed to 8 hours photoperiod from 8 a.m. to 4 p.m. for 4 weeks and the remaining ones allowed to grow under natural day length. After photoperiodic treatment was over the seedlings were transplanted all on the same day in pots with 15 replicates for each treatment.

In 1948 the effects of short days for 6 weeks were studied with two other varieties, *Kataktara* and *Dhairal*. Seeds were sown on April 19, and the same method of short day treatment was used in this experiment.

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* At present Assistant Botanist, State Agricultural Research Station, Chinsurah, West Bengal.

The earthenware pots were filled with an equal quantity of soil dressed with one-eighth part of cowdung manure. Four seedlings were transplanted at first in each pot, after a week thinned down to two uniform plants. The data for tillering, plant height, stem length at the flowering stage, leaf number, ear emergence and grain yield were collected from randomised blocks. More important of these data were analysed statistically.

Winter Rice.—In 1947 the effects of high and low temperatures with or without short days were investigated with one winter variety, *Rupsail.*

Seeds treated as before were vernalised at 35°C. for 10 and 20 days and at low temperature, 10°C. for 5 days, and sown along with the controls between July 3 and 17. Subsequent experimental procedure was similar to that of the previous experiments.

Experimental Results

The effects of different treatments on vegetative growth as indicated by the tillering, plant height, stem length and leaf number of both summer and winter varieties of paddy are presented in Tables I to III.

Tillering.—The influence of short day exposure, high temperature and high temperature followed by short days on tillering of four varieties of summer paddy, *Charnock, Panbira, Dhairal* and *Kataktara,* do not show any appreciable difference as compared with the control (Tables I and II). This is in conformity with the observation noted previously that there is no significant difference between high temperature treated and control plants of two summer varieties, *Dhairal* and *Thoranga*; on the other hand, pre-sowing low temperature treatment caused greater production of tillers (Ghosh, 1949). Sircar and Parija (1949) reported that pre-sowing low temperature (3°C.) treatment induced all the tillers to bear ears in the summer variety, *Jhanji,* but in *Bhutmuri* a marked depressing effect was noticed.

A tendency to increase in tillering by short days with or without pre-sowing temperature treatment is apparent in winter varieties. In *Bhasamanik* a temperature lower than the present one in combination with short days increased the tiller number considerably (Sircar and Parija) and in *Rupsail* the short day effect of increasing tillering is very marked (Sircar and Sen, 1953).

Height.—Two measurements were taken at the flowering stage; one from the surface of the soil up to the topmost leaf tip on the main shoot and another up to the base of this leaf. The first one is the plant height and the second one, the stem length. In summer varieties, *Charnock, Panbira, Dhairal* and *Kataktara,* short day treatment caused reduction of both height and stem length, while high temperature for 10 or 20 days increased both in *Panbira* and *Charnock* (Tables I and II). In two other varieties, *Thoranga* and *Dhairal,* maximum plant height at an initial stage of vegetative growth was obtained by temperature 35°C. for 25 days, while the effect of low temperature was reduction (Ghosh, 1949). It appears that the effect of short days on plant height is similar to low temperature.

Height and stem length at the flowering stage of the winter variety, *Rupsail,* show a reduction in treatments with low or high temperatures plus short days, whereas low or high temperatures alone are without any effect.

Leaf number.—It is interesting to note that in summer paddy short day treatment causes an increase in leaf number with retardation of flowering while high temperature acceleration has no effect on the leaf number (Tables I and IV). In winter paddy, *Rupsail,* short day exposure is associated with reduced leaf number and acceleration of flowering. High or low temperatures alone have no significant differences. From the results it appears that there exists a very high and significant correlation between leaf number and the time of flowering. Analyses of covariances of the data are presented in Tables V to VII. Regression and correlation coefficients to each item in the analyses are given, logarithms being used only on series 1 of *Rupsail.* Regression coefficients are, therefore, independent of the units in which the two variables are expressed, and tend to unity as correlation increases. It is seen that the correlations are in all cases positive and significant.

TABLE I. (1946)

Tiller, height and leaf number (average of 30 plants)

Varieties.	Treatment.	Tiller No. at the flowering stage.	Height and stem length in cm. at the flowering stage.	Leaf No. on the main shoot.
	Series I			
CHARNOCK	Control (A)	3·0	90·8 58·9	14·4
	8 hrs. for 4 weeks (B) ..	2·9	80·3 49·8	15·5
	35°C. for 10 days (C) ..	3·2	90·7 58·9	14·3
	35°C. for 10 days + 8 hrs. for 4 weeks (D). ..	3·1	81·2 44·5	15·8
	Treatment means for the variate leaf number significant at 1% level. D.B. > C.A.			
	Series II			
	35°C. for 20 days (E) ..	3·1	90·1 60·9	15·1
	35°C. for 20 days + 8 hrs. for 4 weeks (F). ..	3·1	73·4 25·6	16·0
	Control (G)	3·1	83·6 56·3	15·2
	Treatment means for the variate leaf number significant at 5% level. F > G.E.			
	Series I			
PANBIRA	Control (A)	2·4	114·9 71·6	14·5
	8 hrs. for 4 weeks (B) ..	2·9	106·7 63·2	15·8
	35°C. for 10 days (C). ..	2·9	117·9 72·8	14·8
	35°C. for 10 days+ 8 hrs. for 4 weeks (D). ..	2·8	103·5 59·9	15·7
	Treatment means for the variate leaf number significant at 1% level. B.D. > C.A.			
	Series II			
	35°C. for 20 days (E) ..	2·6	120·0 81·9	14·8
	35°C. for 20 days+ 8 hrs. for 4 weeks (F). ..	1·9	109·3 67·2	15·4
	Control (G)	2·9	120·5 81·0	15·1
	Treatment means for the variate leaf number not significant.			

TABLE II. (1948)

Tiller and height (average of 20 plants)

Varieties.	Treatments.	Tiller No. at the flowering stage.	Height and stem length in cm. at the flowering stage.
DHAIRAL	Control	4·8	118·3 72·8
	8 hrs. for 6 weeks	5·4	103·1 53·5
KATAKTARA	Control	4·7	119·1 76·2
	8 hrs. for 6 weeks	4·6	117·9 65·1

TABLE III. (1947)

Tiller, height and leaf number (average of 20 plants)

Varieties.	Treatments.	Tiller No. at the flowering stage.	Height and stem length in cm. at the flowering stage.	Leaf No. on the main shoot.
	Series I			
RUPSAIL	Control (A)	4·4	71·7 51·8	15·3
	10°C. for 5 days (B) ..	4·4	72·0 54·6	15·5
	10°C. for 5 days+ 8 hrs. for 6 weeks (C). ..	4·6	49·0 29·9	8·3
	8 hrs. for 6 weeks (D) ..	5·0	48·3 22·2	8·4
	Treatment means for the variate leaf number significant at 1% level. A.B. > C.D.			
	Series II			
	Control (E)	3·3	76·7 53·7	15·1
	35°C. for 10 days (F) ..	4·4	72·5 53·9	15·1
	35°C. for 10 days+ 8 hrs. for 6 weeks (G). ..	4·6	45·9 26·1	8·2
	Treatment means for the variate leaf number significant at 1% level. E.F. > G.			
	Series III			
	Control (H)	4·0	73·4 56·5	13·8
	35°C. for 20 days (I) ..	4·8	73·4 53·8	13·4
	35°C. for 20 days+ 8 hrs. for 6 weeks (J). ..	All died.	..	..

TABLE IV

Leaf number on the main shoot (1948)

Varieties.	Treatments.	No. of leaves.	Calculated value of '*t*'.	'*t*' values.	
				$p = \cdot 05$	$p = \cdot 01$
DHAIRAL	Control	13·7	7·53	2·110	2·898
	8 hrs. for 6 weeks ..	15·5			
KATAKTARA	Control	13·2	13·35	2·101	2·878
	8 hrs. for 6 weeks ..	16·0			

Ear Emergence.—The data for ear emergence of the primary axis and tillers of summer and winter varieties are recorded in Tables VIII to X.

In *Charnock* high temperature of 35°C. for 10 and 20 days induce slight acceleration of flowering in the primary axis, but the effect is not statistically significant, while in *Panbira* a significant earliness by high temperature for 20 days is observed. In all the varieties flowering is retarded significantly with increased number of leaves by short days. This retarding effect does persist even after high temperature treatment indicating that the acceleration of flowering by high temperature is completely annulled. Flowering in the tillers was similarly effected.

Regarding winter paddy, *Rupsail*, low temperature followed by short days has an accelerating effect on the flowering of the primary axis as well as the tillers, while short days alone induce early flowering in the primary axis only. The results are highly significant at 1% level.

TABLE V

Analysis of covariance (variety 'Panbira')

Covariance of number of leaves per plant (L) and the number of days required for flowering (D)

Series I

Sources of covariance.	D.F.	Correlation coefficient.	Regression of *D* on *L*.
Total	23	0·6996	5·6686
Blocks	5	0·3409	2·8248
Treatments	3	0·9081	7·5831
Remainder	15	0·3894	2·9351

Series II

Sources of covariance.	D.F.	Correlation coefficient.	Regression of *D* on *L*.
Total	26	0·3827	3·9722
Blocks	8	0·4175	2·5354
Treatments	2	0·9986	26·1580
Remainder	16	−0·0277	−0·2136

TABLE VI

Analysis of covariance (variety 'Charnock')

Series I

Sources of covariance.	D.F.	Correlation coefficient.	Regression of D on L.
Total	59	0·6497	6·0959
Blocks	14	0·2271	2·0428
Treatments	3	0·9689	7·4892
Remainder	42	0·3231	3·9297
Series II			
Total	23	0·5191	4·3679
Blocks	7	0·3180	1·9013
Treatments	2	0·9986	19·3505
Remainder	14	0·4611	1·9169

TABLE VII

Analysis of covariance (variety 'Rupsail')

Series I

Sources of covariance.	D.F.	Correlation coefficient.	Regression of D on L.
Total	31	0·9866	1·2900
Blocks	7	0·8740	1·2605
Treatments	3	0·9952	1·3000
Remainder	21	0·7884	1·0313
Series I			
Total	31	0·9898	9·7456
Blocks	7	0·8792	10·4061
Treatments	3	0·9978	9·8470
Remainder	21	0·7594	6·6986
Series II			
Total	29	0·9927	7·8619
Blocks	9	0·4501	3·4999
Treatments	2	0·9999	7·9598
Remainder	18	0·7417	3·9047

TABLE VIII. (1946)

Showing number of days for ear emergence and length of ears (average of 30 plants)

Varieties.	Treatments.	No of days from sowing to flowering.			Average length of ears (in cm.).		
		Main shoot.	1st tiller.	Second tiller.	Main shoot.	1st tiller.	Second tiller.
	Series I						
CHARNOCK	Control (A) ..	113·8	115·1	120·0	23·6	23·3	19·2
	8 hrs. for 4 weeks (B)	120·6	122·7	125·0	24·1	23·5	22·6
	35°C for 10 days (C) ..	109·8	112·4	117·8	23·5	22·2	21·4
	35°C. for 10 days + 8 hrs. for 4 weeks (D)	122·1	122·3	125·3	21·9	18·1	13·6
	Treatment means for the variate number of days for ear emergence of the main shoot significant at 1% level. D.B. > A.C.						
	Series II						
	35°C. for 20 days (E)..	110·4	114·7	119·0	22·7	15·1	18·9
	35°C. for 20 days + 8 hrs. for 4 weeks (F)	126·2	125·8	128·0	21·5	22·2	..
	Control (G) ..	113·0	114·9	114·5	19·9	18·4	16·3
	Treatment means for the variate number of days for ear emergence of the main shoot significant at 1% level. F. > G.E.						
	Series I						
PANBIRA	Control (A) ..	110·9	118·6	120·4	20·0	18·8	18·5
	8 hrs. for 4 weeks (B)	122·0	123·4	127·8	20·9	16·0	17·3
	35°C. for 10 days (C)..	109·6	112·5	115·0	23·7	20·1	18·8
	35°C. for 10 days + 8 hrs. for 4 weeks (D)	122·7	125·8	..	23·6	..	..
	Treatment means for the variate number of days for ear emergence of the main shoot significant at 1% level. D.B. > A.C.						
	Series II						
	35°C. for 20 days (E)..	99·8	98·1	98·7	23·8	24·3	23·8
	35°C. for 20 days + 8 hrs. for 4 weeks (F)	113·4	110·0	..	22·5	23·0	..
	Control (G) ..	107·9	109·8	115·3	22·2	22·5	21·8
	Treatment means for the variate number of days for ear emergence of the main shoot significant at 1% level. F. > G. > E.						

TABLE IX. (1948)

Showing number of days for ear emergence and length of ears (average of 20 plants)

Varieties.	Treatments.	No of days from sowing to flowering.			Average length of ears in cm.		
		Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.
DHAIRAL	Control	108·9	108·2	111·5	23·9	22·3	22·8
	8 hrs. for 6 weeks ..	126·6	119·7	123·1	20·6	18·1	20·5

Treatments, shoots, interaction (treatment × shoot) for the variate number of days for ear emergence significant at 1% level. B. > F. D. > E. A. C.

Treatment means for the variate length of ears significant at 1% level.
A. E. C. B. F. D.

Varieties.	Treatments.	Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.
KATAKTARA	Control	106·8	106·9	109·7	25·8	25·2	25·4
	8 hrs. for 6 weeks ..	127·8	121·7	125·7	27·1	25·9	25·7

Treatments, shoots, interaction (treatment × shoot) for the variate number of days for ear emergence significant at 1% level. B. F. > D. > E. C. A.

Treatment means for the variate length of ears not significant.

A—Main shoot of control.
C—1st tiller of control.
E—2nd tiller of control.
B—Main shoot of treated plant.
D—1st tiller of treated plant.
F—2nd tiller of treated plant.

Grain Yield.—The effects of different treatments on the yield were determined by measuring the ear length, number of grains set per ear and finally the weight of the grains. The data are given in Tables XI and XII.

With retardation of flowering grain yield and the number of grains per ear has been adversely affected in *Dhairal* at 1% level, while in *Kataktara* no significant difference was noticed. The differences in the length of the ears, however, did not show marked variation from those of the respective control indicating that the treatments have little effect on ear length. A highly significant increase at 1% level in the number of empty spikelets was noticed in both the varieties indicating that to some extent short day treatment leads to the failure of grain setting. The length of ears, the number of grains and the yield were all adversely affected by short days and temperature treatments in *Rupsail* (Tables X and XI).

From the results obtained in the rice varieties an overall effect of the different treatments on grain yield may be visualised. Short days appear to reduce the yield of the summer varieties because of the failure of a large number of spikelets to form grains (Table XII). While high temperature treatment causes an increased yield together with increased number of fertile spikelets (Ghosh, 1949). Reduction of grain yield in the winter variety by short days is, however, due to the reduction in ear length and the number of total spikelets (Table XI).

TABLE X. (1947)

Showing number of days for ear emergence and length of ears (average of 20 plants)

Varieties.	Treatments.	No of days from sowing to flowering.			Average length of ears in cm.		
		Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.
	Series I						
RUPSAIL	Control (A) ..	126·7	127·8	128·6	19·0	18·39	16·72
	10°C. for 5 days (B) ..	125·3	127·2	128·7	17·2	17·55	16·37
	10°C. for 5 days + 8 hrs. for 6 weeks (C) ..	54·3	98.3	103·4	14·3	13·02	14·14
	8 hrs. for 6 weeks (D) ..	61·8	127·3	126·3	11·5	15·99	15·40

Treatment means for the variate number of days for ear emergence of the main shoot significant at 1% level. A. B. > D. > C.

Treatment means for the variate number of days for ear emergence of the 1st and 2nd tillers significant at 1% level. A. B. D. > C.

Varieties.	Treatments.	Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.
	Series II						
	Control (E) ..	119·8	122·1	123·0	19·3	18·19	15·97
	35°C. for 10 days (F) ..	119·8	121·0	121·9	17·2	..	17·78
	35°C. for 10 days + 8 hrs. for 6 weeks (G) ..	65·3	136·6	143·0	13·0	16·99	15·88

Treatment means for the variate number of days for ear emergence of the main shoot significant at 1% level. E. F. > G.

Treatment means for the variate number of days for ear emergence of the 1st and 2nd tillers significant at 1% level. G. > E. F.

Varieties.	Treatments.	Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.
	Series III						
	Control (H) ..	112·9	113·2	114·3	18·0	17·96	17·17
	35°C. for 20 days (I) ..	114·3	116·8	116·8	18·5	18·48	17·93
	35°C. for 20 days + 8 hrs. for 6 weeks (J) ..	All died.					

DISCUSSION

From the results presented in this paper two outstanding differences in the effects of temperature and day-length on flowering of rice varieties are noteworthy. In summer varieties pre-sowing high temperature accelerates flowering and short days delay it and even annul the acceleration by high temperature. Other workers (cf. Sircar, 1948) have also reported acceleration by high temperature in summer varieties adapted to different tropical climates. These varieties grow in different States of India under conditions of longer day-length and further increase in the day-length appears to have no effect on the flowering (Misra, 1950, 1951). They appear to be intermediate (Allard, 1938) in their day-length requirement as day-length below 10 hours retards flowering and above 13 hours is without any accelerating effect.

TABLE XI. (1947)

Grain yield and number of fertile and empty spikelets per ear

Varieties	Treatments.	Grain yield in gms.			No. of fertile spikelets.			No. of empty spikelets.		
		Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.
	Series I									
RUPSAIL	Control ..	0·710	0·486	0·370	56·6	45·4	31·3	53·4	49·5	46·9
	10°C. for 5 days	0·596	0·490	0·581	43·9	40·1	34·5	43·7	39·1	45·2
	10°C. for 5 days + 8 hrs. for 6 weeks	0·226	0·144	0·107	14·6	10·9	8·3	28·6	24·9	37·1
	8 hrs. for 6 weeks	0·139	0·280	0·196	11·6	19·1	12·6	18·8	57·3	43·9
	Series II									
	Control ..	0·845	0·505	0·406	62·3	41·1	31·0	71·2	67·8	50·1
	35°C. for 10 days	0·714	..	0·257	55·4	..	20·2	40·7	..	53·8
	35°C. for 10 days + 8 hrs. for 6 weeks ..	0·160	0·146	0·109	12·5	12·3	9·4	10·3	66·6	60·8
	Series III									
	Control ..	0·414	0·306	0·290	32·5	21·4	20·3	82·2	75·9	62·5
	35°C. for 20 days	0·597	0·531	0·328	46·8	39·2	26·7	69·2	61·1	68·8
	35°C. for 20 days + 8 hrs. for 6 weeks ..	All died.								

In winter varieties the effect of short photoperiod is different; it induces early flowering irrespective of temperature treatment which is not an obligatory factor for flowering. The short day acceleration of flowering is remarkable; in some varieties it is more than two months ahead of the natural ones. Long day combinations of even 13 hours or above are detrimental to flowering (Saran, 1945; Mukherjee, 1946), as it has been shown by Mukherjee that plants raised in February did not flower till the natural day-length decreased in October or a period of artificial short day applied.

It is interesting to note that the short day effect is diluted—it induces early flowering in the primary axis and a varying degree of earliness in the first two tillers, while later formed tillers are without any photoperiodic response. This variation in the flowering times of the primary axis and tillers has been explained by Sircar and Parija on the assumption of difference in the distribution and concentration of flower-forming substance in the stem apices formed at the time of the photoperiodic exposure. In the present work it has further been noticed that when short day is preceded by low temperature there is an acceleration of flowering in the primary shoot as well as the tillers (Table XI). The cause of this variation in flowering by short photoperiods and in combination with low temperature may be explained that low temperature stimulates early formation of tillers in the seedbeds (Sircar and Parija) and when this is followed by short photoperiods flower-forming substance synthesised in the leaves travels to the apices of the primary shoot as well as the tillers already formed before the photoperiodic exposure resulting in the

TABLE XII. (1948)

Grain yield, and number of fertile and empty spikelets per ear

Varieties.	Treatments.	Grain wt. in gms.			No. of fertile spikelets.			No. of empty spikelets.		
		Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.	Main shoot.	1st tiller.	2nd tiller.
DHAIRAL	Control ..	2·406	1·928	2·108	95·7	70·8	81·0	20·6	24·4	21·8
	8 hrs. for 6 weeks ..	0·903	0·895	0·882	39·3	35·3	39·6	46·1	31·1	37·8

Treatment means for the variate grain weight and number of fertile spikelets significant at 1% level. A. E. C. > B. D. F.

Treatment means for the variate number of empty spikelets significant at 1% level. B. F. D. C. E. A.

Varieties.	Treatments.	Grain wt. Main shoot.	Grain wt. 1st tiller.	Grain wt. 2nd tiller.	Fertile Main shoot.	Fertile 1st tiller.	Fertile 2nd tiller.	Empty Main shoot.	Empty 1st tiller.	Empty 2nd tiller.
KATAKTARA	Control ..	2·693	2·398	2·340	133·8	119·3	117·7	22·9	26·0	30·7
	8 hrs. for 6 weeks ..	2·606	2·469	2·160	128·6	129·0	107·4	76·9	59·0	74·7

Treatment means for the variates grain weight and number of fertile spikelets not significant.

Treatment means for the variate number of empty spikelets significant at 1% level. B. F. D. > E. C. A.

A—Main shoot of control.
C—1st tiller of control.
E—2nd tiller of control.
B—Main shoot of treated plant.
D—1st tiller of treated plant.
F—2nd tiller of treated plant.

initiation of floral primordia, while in absence of tillering in the seedbed of short day treated plants flower-forming substance synthesised during the treatment accumulates at the growing apex of the primary shoot and accelerates its flowering. It thus appears that the short day effect on rice is different from other short day plants. In winter rye the tillers show the same behaviour as the primary shoot indicating that the whole plant is affected by the treatment (Purvis and Gregory, 1937) and in Xanthium (Hamner and Bonner, 1938) the photoperiodic stimulus is not only transmitted to non-induced parts of the plant, but these parts continue to produce flowers indefinitely even if the induced plant part is removed. This led Lang (1952) to consider the possibility that the photoperiodic effects are self-perpetuating. Since the tillers in rice formed after the exposure failed to show the response, and they flower only after a second dose of short day treatment (Mukherjee, 1946), it follows that the effect is localised and related to the concentration of the substance formed during the effective photoperiod, and there is no indication of the stimulus transmitted to the later formed tillers of the same plant. Taking this fact into consideration it is difficult to conceive that the photoperiodic effect in rice is self-perpetuating.

With acceleration of flowering by short days alone and in combination with the low temperature, a significant decrease in leaf number on the primary axis of

Rupsail is noticed. Between high and low temperature no significant difference is observed, while in summer paddy short photoperiods alone and in combination with high temperature increase the leaf number with retardation of flowering. From the results it appears that there exists a very high and significant correlation between leaf number and the time of flower formation (Tables V to VIII). Similar relation between leaf number and the time of flower formation has been reported by McKinney and Sando (1935) in wheat and Purvis and Gregory (1937) in Petkus winter rye. Similar to the effects of short days alone and in combination with low or high temperatures on leaf number, plant height and stem length are also appreciably reduced together with grain yield where marked acceleration of flowering is noticed. While the tillering is not reduced, on the contrary, increase in the number by short days has been reported by Sircar and Sen (1953). The decrease in grain yield is however due to the reduction in ear-length and the number of spikelets (Tables XI and XII). Leopold (1949) reported increase in tillering in winter barley with decrease in stem length. It thus appears that with the reduction of leaf number and stem length by short days, the materials for the growth of extra leaves and stem length become available for the production of more tillers.

In summer varieties, the effects of day length and temperature are different; short photoperiods alone and in combination with high temperature reduce plant height, stem length and grain yield, but the total number of leaves on the main shoot is increased and the flowering retarded. On the other hand, high temperature induces early flowering with increased grain yield. In these varieties the short day effect in addition to delay in flowering leads to the reduction in the number of spikelets and a large percentage of failure of grain formation (Table XII). It is not possible without further work to say precisely how short days cause a large number of spikelets empty. Since the ear emergence has taken place and a large number of spikelets found empty, it follows that flower initiation and floral organisation have taken place, possibly the floral maturation consisting of the differentiation of sporogenous tissues or pollen or embryo-sac development has been adversely affected by short days.

In recent years considerable attention has been paid to study the physiology of flowering. Based on the general features of vernalisation and photoperiodism several possibilities have been suggested by workers in this field to explain the changes from vegetative to flowering state. Two recent reviews by Sen (1951) and Lang (1952) have presented the problem in greater detail. The points at issue are how far these hypotheses can explain the peculiarities noticed in rice plant.

Cajlachjan's hypothesis (1937) on the formation of a transmissible stimulus-florigen has been further elaborated by Lang (1952) with several arguments. One important consideration in this is that the substance is self-perpetuating. But the substance is not in rice has been argued before. It has been suggested by a group of workers (Lang, 1952) that the effect of day length consists not in the formation of flower-promoting substance under inductive condition but in the formation of flowering-inhibiting substances under non-inductive conditions. These inhibiting substances are identified with auxins, and photoinduction involves the production of anti-auxins. But Leopold and Thimann (1948, 1949) have shown that the auxins may not be acting simply in opposition to flowering but number of flowers increased by low concentration of auxin and in pineapple flowering is induced by auxin (Clark and Kerns, 1942). Certain considerations from the behaviour of rice plant are contrary to this assumption. On the basis of the formation of growth inhibiting substances during non-inductive condition it would be difficult to explain the fact that only the main shoot of rice plant flowers under short day exposure but when the tillers after short day exposure kept in long day for more than one month did not flower ; flowering was, however, noticed in these tillers after four days short day exposure (Mukherjee, 1946). If the flower-inhibiting substance is formed in the non-inductive condition, the long day exposure would lead to large accumulation of this substance in the tillers. It is very unlikely that short day exposure of the tillers for 4 days would neutralise all the accumulated inhibiting effect and flowering initiated. In earlier papers from this laboratory attempts have been made to explain the behaviour of the tillers on the assumption that some substance is formed under inductive condition and the subsequent behaviour of the tillers is related to the concentration of this substance. Whether this is a flowering hormone or something else is not possible to say with the data at hand. To elucidate this further work is in progress in this laboratory.

Summary

The effects of high and low temperature during germination with or without subsequent short day exposure of seedlings on tillering, height, leaf number, ear emergence, number of fertile and empty spikelets in summer (*Aus*) and winter (*Aman*) varieties of rice have been investigated.

In summer varieties low temperature treatments are without any acceleration of flowering. High temperature accelerates flowering but short days delay it and annul the high temperature acceleration. On the other hand, short day induces early flowering of the winter variety, acceleration being noticed in the primary axis only, but when short day exposure is preceded by low temperature flowering is accelerated in the primary shoot as well as the tillers. Low and high temperatures alone do not seem to have any influence on the flowering of the winter variety.

Associated with the acceleration of flowering there occurs a reduction in leaf number, while in summer varieties short days increase the number. Height and stem length are reduced both in summer and winter varieties by short days with or without low temperature treatment. High temperature, on the other hand, has increased the height and stem length. The effects on tillering are different; the number is not reduced, on the contrary, an increase by short day or low temperature treatment has been reported.

Short days appear to reduce the grain yield both in summer and winter varieties; the reduction in summer varieties is due to the failure of a large number of spikelets to set grains, while in winter variety reduction is associated with decrease in ear length.

The results with rice plant have been discussed in the light of recent views on the physiology of flowering.

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