STUDIES IN THE PHYSIOLOGY OF RICE

V. Vernalisation and Photoperiodic Response in Five Varieties.

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Introduction.

In previous papers (Sircar, 1942, 1944, 1946) the effectiveness of short days on the acceleration of flowering and increase in growth rate and grain yield of one variety of winter paddy has been reported. On the basis of the results a method of vernalisation of rice by the application of short days to seedlings in the seed bed has been suggested and its scope for practical purpose fully discussed. Vernalisation response is varietal in character and it remains to be seen how different varieties grown in West Bengal react to vernalisation treatments. It is desirable to find out the varieties that may show acceleration of flowering with increased grain yield or without adverse effect on the yield or considerable reduction in flowering duration. The results presented in this paper are obtained from the work continued further with five varieties of rice grown in West Bengal. Some of the more important results have already been briefly reported (Sircar and Parija, 1945), and are here presented in their entirety. Besides the possibilities of the practical application of the results these have important bearing on the developmental physiology of rice plant of which an adequate picture has not yet been presented.

Materials and Methods.

Pure strains of three winter (*Aman*) varieties, e.g. *Rupsail, Patnai 23* and *Bhasamanik*, and of two summer (*Aus*) varieties, e.g. *Jhanji 34* and *Bhutmari 36*, were used in this investigation. The treatments applied to the varieties are as follows:—

(1) Exposure of seedlings of *Rupsail* and *Patnai* to short days of 8 and 10 hours for varying periods.

(2) Pre-sowing low temperature (3°C.) treatment of seeds of *Bhasamanik, Jhanji 34* and *Bhutmari 36* for varying periods.

(3) A combination of the treatments 1 and 2 in which the seedlings from low temperature treated seeds of *Bhasamanik, Jhanji* and *Bhutmari* were given 8 hours' short days for different periods.

The method of applying short photoperiods to seedlings of different varieties was same as in previous work (Sircar, 1946). For low temperature treatments seeds were first soaked in water for 6 hours at room temperature. After drying up the superficial water with the help of a blotting-paper, seeds were put in unglazed porcelain pots and placed in a moist chamber. The moist chamber selected in this work was a rectangular glass jar with removable glass lid. The inside of the jar as well as the lid was lined with blotting-paper and sufficient water was put in the jar to keep the paper moist throughout the period of exposure. A Petri dish containing 20% solution of potassium hydroxide was kept inside the chambers to absorb CO_2 respired by the seeds. The moist glass jar was then placed in a refrigerator having a temperature 2-3°C. Fresh air was supplied to the seeds every day by opening the lid of the chamber. Chilled seeds were then sown in two seed beds for each treatment. Unchilled seeds as control were also sown on the same day. Short photoperiod of 8 hours for 4 weeks was then applied to 15 days old seedlings from chilled seeds in one of the seed beds; the other seed bed was left to receive normal day length. After the short day treatment was over 10 seedlings from each seed bed were transplanted in 10 earthenware pots. Rice is usually grown under wet conditions and this was fulfilled in these experiments by transferring the transplanted seedlings to cemented tanks (Fig. 1) provided with stoppered outlets for maintaining constant water level. In this experiment soil in the pots was kept just below the water level.

EXPERIMENTAL RESULTS.

Variety—*Rupsail.*

Response to short day treatment was remarkably exhibited in this variety, the effect being manifested in pronounced acceleration of ear emergence. The plants in all the seed beds receiving short day treatments produced flowers in the 6th week of the treatment (Fig. 2). After the end of the treatments, treated as well as control plants were allowed to ripen in seed beds under natural day length. As there were no tillers produced in these plants, the data for growth, flowering and yield measurements were collected from these single shoot plants and presented in Table I.

TABLE I.

Leaf number, flowering behaviour and yield measurements of *Rupsail* (average of 10 plants) in seed bed; sowing date 20-6-44.

TREATMENT.		Date of flowering.	Flowering duration.	Leaf No. at which plants flowered.	No. of grains set per ear.	Total No. of spikelets per ear.	Percentage of grains set per ear.	Weight of individual grains in gm.	Grain yield in gm.
Hours per day.	Periods in weeks.								
8	4	9-8-44	50	10	44·5	53·5	83·1	0·0162	0·71
8	5	7-8-44	48	10	56·3	69·1	81·5	0·0156	0·84
8	6	7-8-44	48	10	47·8	54·7	87·3	0·0159	0·74
10	4	8-8-44	49	10	52·4	65·8	89·6	0·0162	0·83
10	5	6-8-44	47	10	63·3	68·8	92·0	0·0154	0·95
10	6	9-8-44	50	10	59·2	74·9	79·0	0·0160	0·94
Control	Control	31-10-44	133	16	65·5	87·6	74·7	0·0158	1·04

It would appear that ear emergence in the main shoots after short day exposure takes place within 50 days from sowing while in the control plants it took about 133 days. With the acceleration of ear emergence leaf number on the main shoot is considerably reduced. The treated plants flowered at the 10th leaf stage whereas the untreated ones had the 16th leaf as the flag leaf. The ears from the main shoots of short day plants were ready for harvest by September 17, 1944, while the control plants were harvested on December 12, 1944. Thus an earliness of 85 days in harvesting was obtained. The grain yield of the main shoot in all these cases appeared to have been adversely affected by the treatments as the grain weight, total number of spikelets and grains set per ear of the control were greater than in the treated one. The treatments, however, did not produce any adverse effect on grain setting and weight of individual grains; on the contrary, an indication of increased percentage of grain setting is noticed in the treated shoots. It is interesting to note that although the main shoot of the treated plants matured in a remarkably short period, this did not affect the grain weight as compared with that of the control.

In order to ascertain the effects of short day treatments on the formation of tillers in this variety after transplantation and subsequent behaviour of these tillers in respect of ear emergence and grain yield, 10 seedlings from each seed bed were transplanted in pots after 6 weeks' treatment. The flowering duration and the yield of the tillers formed subsequently were recorded and the relevant data are presented in Table III. As noted before there was no tiller formation in the seed bed, but soon after transplantation tillering was very rapid in both treated and control plants and in course of a month a large number of tillers formed. From three tiller counts noted below (Table II) it would appear that there is no appreciable difference in tillering between the treated and the control plants.

TABLE II.

Tiller and height of *Rupsail* (average of 10 plants).

Treatment.		9-9-44	7-10-44	4-11-44 Ear bearing tillers.	Height of plants at the flowering stage (in cm.).
Hours per day.	Periods in weeks.				
8	4	9·4	15·1	12	132·5
8	5	8·8	15·5	12·8	135·0
8	6	9·6	16·4	13·1	140·0
10	4	7·5	15·0	10·8	128·7
10	5	8·0	14·6	10·9	145·0
10	6	8·2	14·3	12·0	145·0
Control	Control	8·9	15	11·5	116·2

The data further show that some of the later formed tillers of this variety do not bear ears and in this respect it differs from *Bhasamanik* (Sircar, 1946) and *Patnai* (Table VI) where the treatment induced a greater number of ear bearing tillers. The treatments had an effect in increasing the height of the plants, tallest plants being produced with 10 hrs. for 5 and 6 weeks (Fig. 3). It has been noted before that the main shoots of plants under different treatments flowered within 50 days whereas the first tillers of all the treated plants except that of the plants of 8 hrs. for 4 weeks flowered 20–22 days after the main shoots; similarly the second tillers were 10–13 days behind the first tillers and in the remaining tillers flowering was about 6 days earlier than in the control (Table III). Flowering in the tillers of the control plants was completed within 3 days. Thus it appears that short day exposure of this variety results in uneven flowering of the tillers and a varying degree of earliness as compared with the corresponding tillers of the control plants (Fig. 3). Without further data it is not possible to trace the cause of this variation. It may, however, be argued that the photoperiodic stimulus was perceived by the main shoot and the two tiller buds which might have been formed or whose cell initials laid down in the growing point at the time of short day exposure, while the tillers or cell initials formed after the period of exposure did not receive the stimulus conducive to earliness. In order to throw further light on this interesting point it will be necessary to study the development of the growing point at the time of photoperiodic exposure.

TABLE III.

Flowering behaviour of *Rupsail* tillers (average of 10 plants). Dates of sowing: 20-6-44 and of transplanting: 12-8-44.

Treatment.	DATE OF FLOWERING.			FLOWERING DURATION.		
	First tiller.	Second tiller.	Remaining tillers.	First tiller.	Second tiller.	Remaining tillers.
8 hrs. 4 weeks	7-9-44	28-10-44	29-10-44	79	130	131
8 hrs. 5 weeks	27-8-44	7-9-44	28-10-44	68	79	130
8 hrs. 6 weeks	29-8-44	11-9-44	29-10-44	70	83	131
10 hrs. 4 weeks	29-8-44	9-9-44	28-10-44	70	81	130
10 hrs. 5 weeks	28-8-44	9-9-44	29-10-44	69	81	131
10 hrs. 6 weeks	28-8-44	8-9-44	28-10-44	69	80	130
Control	2-11-44	3-11-44	3-11-44	135	136	136

Ear length and number of grains set in the first and second tillers were measured in order to ascertain how far the treatments affect these two characters contributing to grain yield. The average data of 10 plants with two tillers per plant presented in Table IV show reduction in ear length in 10 hours for 4 and 6 weeks while in others differences from the control are very little. The number of grains set in these two ears is less than that of the corresponding ears of the control plants, and this difference is statistically significant at 1% level (Table V). The total number of spikelets is greater while the number of empty spikelets is less in the control but this is not significant. These results show that although short day exposure of this variety resulted in a significant reduction in the number of grains of the tillers showing marked earliness, but the total grain yield determined from all the ears of the plant (Table IV) do not show this effect as variations between the treated and the control do not approach the level of significance.

TABLE IV.

Yield measurements of *Rupsail* (average of 10 plants).

TREATMENT.		Length of ear in cm.	No. of grains set per ear.	No. of empty spikelets per ear.	Total No. of spikelets per ear.	Percentage of grains set per ear.	Grain yield in gm.
Hours per day.	Periods in weeks.						
8	4	21·0	154·7	33·5	188·2	82·2	26·69
8	5	23·7	165·3	41·4	206·7	80·0	30·18
8	6	20·0	156·2	43·3	199·5	78·3	28·74
10	4	18·7	143·8	43·9	187·7	76·6	22·06
10	5	21·5	170·8	34·1	204·9	83·4	26·39
10	6	19·2	150·4	46·2	196·6	76·5	25·48
Control	..	22·2	176·6	35·3	212·4	83·1	28·66

TABLE V.

Analysis of variance of the data for grain yield of *Rupsail*.

	Sources of variance.	Degrees of freedom.	Vari-ance.	Ratio.	CRITICAL DIFFERENCE. 5% level.	CRITICAL DIFFERENCE. 1% level.
Grains set per ear	Between treatments	6	2720·40	8·49*	11·32	15·05
	Within treatments	63	320·36			
Number of empty spikelets per ear	Between treatments	6	535·87	2·19	9·83	13·14
	Within treatments	63	244·17			
Grain yield per plant	Between treatments	6	71·74	3·44	4·08	5·43
	Within treatments	63	20·87			

* Indicates significance at 1% level.

Variety—*Patnai.*

The effects of the treatments on vegetative growth as indicated by the rate of tillering and changes in height and leaf number are presented in Tables VI and VII. From five tiller counts at different dates it was noticed that at the beginning there was not much difference in the rates of tillering between the treated and control plants, but at later periods of growth the treated plants showed a marked increase in tillering. Application of photoperiods for 8 and 10 hrs. for 5 and 6 weeks produced greater number of ear bearing tillers than in the controls and photoperiods of 4 weeks, highest number being obtained with 10 hours for 5 and 6 weeks. These results are similar to that noted in another winter variety *Bhasamanik* (Sircar, 1946) where an exposure of seedlings to effective photoperiods resulted in a greater number of ear bearing tillers than in the control.

TABLE VI.

Tiller number in *Patnai* (average of 10 plants).

Treatment.	24-8-44	14-9-44	5-10-44	26-10-44	16-11-44 Ear bear-ing tillers.
8 hrs. for 4 weeks	2·8	5·4	9·3	13	9·2
8 hrs. for 5 weeks	3	5·8	9·8	13·8	11·5
8 hrs. for 6 weeks	3·2	6	10	14·6	12·4
10 hrs. for 4 weeks	3	5	9·4	14·5	11·0
10 hrs. for 5 weeks	3·5	7·2	12·8	16·4	15·2
10 hrs. for 6 weeks	3	7·5	13·2	16·8	15
Control	3·7	5·4	8·6	12·9	9

An increase in the height of the plants at the time of ear emergence was noted in the treatments with 10 hours for 5 and 6 weeks and 8 hours for 6 weeks (Table VII). The total number of leaves produced on the main shoot of the control plant is 20, the last one being the flag leaf and this number was reduced to 12 by the treatments inducing a considerable reduction in its flowering duration (Table VII). A difference

TABLE VII.

Weight, leaf and flowering data of *Patnai* (average of 10 plants).
Dates of sowing: 20-6-44 and of transplanting: 12-8-44.

TREATMENT.		Height of plants (in cm.) at the time of ear emergence.	Leaf No. on the main shoot.	FLOWERING DATE.		FLOWERING DURATION.	
Hours per day.	Periods in weeks.			Main shoot.	Remaining tillers.	Main shoot.	Remaining tillers.
8	4	113·7	20	5-11-44	5-11-44	138	138
8	5	113·7	13	21-9-44	3-11-44	93	136
8	6	131·2	12	11-9-44	3-11-44	83	136
10	4	112·5	20	3-11-44	3-11-44	136	136
10	5	146·2	12	7-9-44	2-11-44	79	135
10	6	140·0	12	8-9-44	2-11-44	80	135
Control	Control	117·5	20	3-11-44	4-11-44	136	137

of 10 days in ear emergence was noticeable between the production of the 12th and the 13th leaf in 8 hours' photoperiods. It is interesting to note that the plants that responded to treatments by inducing earliness in the main shoot showed an increase in height and reduction in leaf number.

An interesting feature in the flowering behaviour of this variety is the main shoot of the treated plants flowering within 80–83 days, while the remaining tillers flowered at about the same time as the control plants after 135–137 days. It appears that the photoperiodic perception for a period of 6 weeks so as to induce early flowering is limited to the main shoot while the tillers remain unaffected. This acceleration of flowering resulted in a considerable reduction in ear length and

TABLE VIII.

Yield measurements of *Patnai* (average of 10 plants).

Treatment.	Length of ear in cm.	Total No. of spikelets per ear.	Number of grains set per ear.	Percentage of grains set per ear.	Yields in gm. per plant.
8 hrs. for 4 weeks .. T_1	20·7	184·8	148·8	80·49	34·82
8 hrs. for 5 weeks .. T_2	20·0	171·7	136·4	79·41	32·64
8 hrs. for 6 weeks .. T_3	20·0	178·4	143·0	80·15	33·51
10 hrs. for 4 weeks .. T_4	20·7	176·4	142·8	80·95	35·92
10 hrs. for 5 weeks .. T_5	19·7	181·5	146·7	80·80	36·87
10 hrs. for 6 weeks .. T_6	18·2	167·0	133·3	79·85	30·39
Control .. .. T_0	21·7	182·2	151·5	83·17	39·95

grain yield of the main shoot similar to that noted in *Rupsail*. Although the treatments failed to induce earliness in the tillers, their number increased (Table VI). Production of tillers from the treated plants continued even after the main shoot flowered and in this respect 10 hours' photoperiod was more effective than 8 hours'. In order to assess this effect on tillering in respect of ear length and number of grains formed measurements from the ears of first and second tillers were made at harvest. The data presented in Table VIII are the mean of 20 tillers of 10 plants per treatment, and would show an indication of decrease in ear length and reduction in the total number of spikelets per ear in different treatments.

The number of grains set in the control tillers was found to be higher than that of other treatments and this effect is statistically significant at 1% level (Table IX), but the variation in the number of spikelets is not significant. The total grain yield determined from all the ears of a plant was found to decrease in various treatments (Table VIII). Analysis of variance (Table IX) shows that the treatments as a whole are not significantly different from the control. But while designing the experiment, it was also the purpose to compare the individual treatments against the control. This shows that there is no significant difference in yield between T_1, T_4 and T_5 and control, while T_2, T_3 and T_6 are significantly lower than the control at 5% level. Although the number of ear bearing tillers is greater in the plants showing photoperiodic response, but the grain yield as compared with the control has decreased because of reduction in the number of grains set per ear.

TABLE IX.

Analysis of variance of the data for grain yield of *Patnai*.

	Degrees of freedom.	Variance.	Ratio.	Critical Difference.	
				5% level.	1% level.
Setting of grains per ear.	Between treatments = 6	855·70	4·98*	8·28	11·02
	Within treatments = 63	171·95			
Grain yield per plant.	Between treatments = 6	96·35	2·11	6·03	8·02
	Within treatments = 63	45·68			

* Indicates significance at 1% level.

Variety—*Bhasamanik*.

One of the interesting features noticed in the low temperature treatment of this variety was that tillers were produced in the seed bed. Low temperature stimulation led to luxuriant growth of the seedlings, which were taller and healthier than in the control. Table X shows that pre-sowing low temperature treatment for varying periods and in combination with short days produced greater number of tillers than in the control, maximum number being noticed in 10 days' low temperature followed by short day exposure of seedlings. In all these cases the number of tillers increases up to a certain stage of the growth of the plants then some of them die off without bearing ears. Although death of the tillers was more rapid in the treated plants, the number of ear bearing tillers was always greater than in the control.

TABLE X.

Tiller number in *Bhasamanik* (average of 10 plants).

TREATMENT.	1-5-44	22-5-44	12-6-44	3-7-44	24-7-44	14-8-44	4-9-44	25-9-44	14-10-44
Pre-sowing low temperature for 5 days	7·5	11·5	32·8	41·1	38·5	35·8	33·5	30·5	25·3
Pre-sowing low temperature for 5 days + short days for 4 weeks ..	3	8	29	40	39	37·7	36·4	31·3	26·2
Control	1·5	4	24·5	32·2	35	33·2	34·5	31·7	23·5
TREATMENT.	28-4-44	19-5-44	9-6-44	30-6-44	21-7-44	11-8-44	1-9-44	22-9-44	13-10-44
Pre-sowing low temperature for 10 days	4·8	6·4	20·2	29·8	37·5	38·4	33·0	31·5	27·4
Pre-sowing low temperature for 10 days + short days for 4 weeks ..	1·8	2·2	23·5	32·5	40·2	41·5	37·5	33·8	28·0
Control	1·7	1·5	16·5	23·5	28·8	25·2	24·8	21·6	18·5
TREATMENT.	27-4-44	18-5-44	8-6-44	29-6-44	20-7-44	10-8-44	31-8-44	21-9-44	12-10-44
Pre-sowing low temperature for 15 days	5·1	7·2	11·0	25·2	34·5	36·0	33·0	27·0	24·5
Pre-sowing low temperature for 15 days + short days for 4 weeks ..	2·0	3·1	8·0	27·2	38·5	43·0	36·2	30·1	26·0
Control	1·0	1·5	7·5	19·5	27·0	29·0	28·2	22·5	20·0

Height of the plants measured from the base to the tip of the last leaf is increased by these treatments (Table XI).

At the earlier stages of growth the height differences between the treated and control plants were very little, but a marked increase was noticed at later stages of growth. It is to be noted that of all the treatments 10 days' pre-sowing low temperature followed by short day treatment of seedlings produced tallest plants (Fig. 4) with maximum tillers.

TABLE XI.

Height in cm. of *Bhasamanik* (average of 10 plants).

Treatment.	30-6-44	5-8-44	9-9-44	At the time of ear emergence.
Low temperature for 5 days	45·0	93·7	146·0	151·0
Low temperature for 5 days and short days for 4 weeks	45·0	95·0	145·0	152·0
Control	43·5	95·0	130·0	138·7
Low temperature for 10 days	45·0	100·5	136·55	157·0
Low temperature for 10 days and short days for 4 weeks	45·5	102·5	180·0	207·0
Control	45·0	90·0	132·0	146·2
Low temperature for 15 days	41·0	92·5	153·0	171·5
Low temperature for 15 days and short days for 4 weeks	40·0	97·5	152·5	175·7
Control	42·5	98·7	133·5	151·5

The effects of the treatments on this variety are so marked that without further statistical analysis it may be concluded that low temperature alone and in combination with short day stimulation leads to an increase in height, and the number of vegetative and ear bearing tillers. Table XII shows the mean date of ear emergence in different treatments. Bell (1939) and Ramiah (1933) have remarked that in a pure line population the satisfactory criterion for finding out the date of ear emergence is the date at which about 50% of the plants flower. The data calculated on this basis show that in all the three sowings treated plants flowered earlier than the control.

The analysis of variance (Table XIV) has, however, shown a highly significant earliness with 5 days' low temperature treatment and significance at 5% level with 10 days' low temperature treatment, while with 15 days' treatment mean earliness of 8 days was not even significant. It may be noted here that the dates of sowings were different in different treatments, but flowering in all the treated plants took place at about the same time. Similarly the control plants of different sowings flowered approximately at the same time (Table XII).

The effects of different vernalisation treatments on yield were determined by measuring the number of ears per plant, length of ears, number of grains set per ear and finally the total grain yield per plant. Harvesting was done after 5 weeks from the date of ear emergence. The grain weight was recorded after drying the ears in the sun for a week. From each plant two ears from the main shoot and first tiller were taken for yield measurements and the average data of the ears of 10 plants are presented in Table XIII.

TABLE XII.

Ear emergence of *Bhasamanik* (average of 10 plants).

Sowing.	Treatment.	Date of sowing.	Date of ear emergence.	Earliness in days over the control.
1	Low temperature for 5 days	21-3-44	16-10-44	7
	Pre-sowing low temperature for 5 days + short day for 4 weeks	21-3-44	17-10-44	6
	Control	21-3-44	23-10-44	..
2	Low temperature for 10 days ..	29-3-44	18-10-44	5
	Low temperature for 10 days + short day for 4 weeks	29-3-44	18-10-44	5
	Control	29-3-44	23-10-44	..
3	Low temperature for 15 days ..	3-4-44	16-10-44	7
	Low temperature for 15 days + short day for 4 weeks	3-4-44	15-10-44	8
	Control	3-4-44	23-10-44	..

TABLE XIII.

Yield measurements of *Bhasamanik* (average of 10 plants).

No. of sowing.	Treatment.	Ear length in cm.	Total No. of spikelets.	No. of grains set per ear.	Per cent of grains that set per ear.	Yield per plant in gm.
1	Low temperature for 5 day + short day of 8 hours for 4 weeks ..	24·12	191·2	147·3	77·03	38·78
	Low temperature for 5 days	22·56	173·7	138·6	79·79	39·70
	Control	22·37	172·2	131·2	76·19	34·23
2	Low temperature for 10 days + short day of 8 hours for 4 weeks ..	23·56	192·90	147·85	76·64	46·57
	Low temperature for 10 days	24·18	207·45	162·55	78·35	40·30
	Control	24·37	212·50	168·25	79·17	41·81
3	Low temperature for 15 days + short day of 8 hours for 4 weeks ..	24·25	207·95	177·45	85·33	53·08
	Low temperature for 15 days	24·18	214·85	178·1	82·89	54·65
	Control	23·37	189·50	149·95	79·12	39·00

The length of ear under different treatments does not show marked variation from that of the respective controls indicating that the treatments have very little effect on the length of earhead. Interesting results have, however, been obtained in the number of grains per ear. Table XIII shows that in sowings 1 and 3 the number of grains set in the treated plants is higher than that of the control plants while in the sowing 2 the number has been found to be greater in the control. It is to be noted that about 82 to 85% grains set in the treated plants under third sowing. The statistical analysis shows (Table XIV) this effect is highly significant. Table XIV shows a highly significant increase in grain yield with 15 days' low temperature treatment while with treatments for shorter duration the yield increase does not reach the level of significance.

TABLE XIV.

Analysis of variance of the data for *Bhasamanik* (average of 10 plants).

Analysis.	Sources of variance.	Degrees of freedom.	Variance	Ratio.	CRITICAL DIFFERENCE.	
					5% level.	1% level.
Temperature effect						
5°C.	Between treatments	2	73·05	14·58*	2·07	2·30
	Within treatments	27	5·01			
10°C.	Between treatments	2	37·65	5·2*	2·46	3·33
	Within treatments	27	9·29			
15°C.	Between treatments	2	527·05	2·51	13·30	17·96
	Within treatments	27	209·99			
Setting of grains per ear	Between treatments	10	4707·5	9·69*	13·78	18·0
	Within treatments	99	485·82			
Grain yield per plant	Between treatments	10	450·51	4·25*	9·11	12·05
	Within treatments	99	106·02			

* Indicates significance at 5% level.

Varieties—*Jhanji* and *Bhutmari*.

The treatments adopted for these varieties have shown marked effect in the number of ear bearing tillers (Table XV). In *Jhanji* low temperature induced all the tillers fertile while with low temperature followed by short day treatment the number of fertile tillers was about the same as in the control plants. The plants having only short day exposure had the largest number of ear bearing tillers. A marked depressing effect on the production of fertile tillers was noticed in *Bhutmari*. Although short day produced maximum number of tillers (Fig. 5), only 55% of them were fertile. Similarly in other treatments a large reduction of fertile tillers was noticed. The total number of leaves produced on the main shoot of *Jhanji* under different treatments was 17. There was no reduction of leaf number and no earliness in ear emergence in this variety by vernalisation methods. On the other hand, in *Bhutmari* the number of leaves was 16 in the treated plants against 17 in the control and an earliness of 13 days was obtained by the combined effect of low temperature and short days (Fig. 5). Short day alone and low temperature followed by short day treatment in *Jhanji* showed increased yield of 16 and 11% respectively over the control. Though the percentage of grain setting was less in treated plants the increase in yield was due to greater number of surviving tillers. The treatments did not show much change in the grain yield of *Bhutmari*, except in the plants having pre-sowing low temperature followed by short day exposure when an increased yield of 8% accompanied by increased percentage of grain setting was noticed. In order to ascertain whether the treatments had any effect on the weight of individual grains, 1,000 grain weight from each treatment was taken. The data presented in Table XV would show very little change in the weight of the grains as affected by the vernalisation treatments.

TABLE XV.

Growth and flowering data of *Jhanji 34* and *Bhutmari 36* (average of 10 plants).

Variety.	Treatment.	Date of: Sowing.	Date of: Transplantation.	No. of vegetative tiller.	No. of ear bearing tillers.	Leaf No. on the main shoot.	Flowering duration.	Percentage of grains set per ear.	Grain yield per plant in gm.	Grain wt. in gm.
Jhanji 34	Low temperature at 2°-3°C. for 10 days	25-4-44	9-6-44	27·5	27·4	17	119	78·48	39·06	0·023
	Short days of 8 hrs. for 4 weeks ..	15-4-44	31-5-44	33·6	29·2	17	119	80·23	44·40	0·022
	Low temperature at 2°-3°C. for 10 days + short days of 8 hrs. for 4 weeks ..	25-4-44	9-6-44	25·6	23·6	17	116	83·70	41·80	0·023
	Control ..	25-4-44	9-6-44	28·6	24·9	17	120	85·00	37·21	0·023
Bhutmari 36	Low temperature at 2°-3°C. for 10 days	25-4-44	9-6-44	30·5	22·1	16	103	91·35	46·52	0·024
	Short days of 8 hrs. for 4 weeks ..	15-4-44	31-5-44	40·8	22·7	16	110	76·80	42·68	0·024
	Low temperature at 2°-3°C. for 10 days + short days of 8 hrs. for 4 weeks ..	25-4-44	9-6-44	23·6	19·2	16	97	92·36	50·50	0·029
	Control ..	25-4-44	9-6-44	34·8	25·7	17	112	81·13	46·50	0·023

DISCUSSION.

Vernalisation methods have been tried in pot culture experiments with five varieties of rice grown in West Bengal, and results of agricultural importance indicated in some of them. Pre-sowing low temperature treatment of seeds of three varieties, one winter—*Bhasamanik*, and two summer—*Bhutmari* and *Jhanji*, have given interesting results to note. Chilling led to an increase in the tillering rate which was noticed even in the seed beds of *Bhasamanik*. Low temperature followed by short day treatment has further increased the tillering rate and the number of ear bearing tillers in two varieties, while in *Bhutmari* the number of ear bearing tillers was greatly reduced. Low temperature combined with short days has greatly increased the height of the variety, *Bhasamanik*. The effects of low temperature treatment on the tillering rate of the three varieties of wheat has been studied by Bell (1936). He has observed that the treatment resulted in an increase in the tillering rate at the earlier stages of growth. But at harvest there was considerable reduction in the number of ear bearing tillers in two varieties and the third variety was not subject to reduction in the ear number. From this he came to the conclusion that the vernalisation treatment may reduce the grain yield. It is of interest to note that increase in the number of ear bearing tillers by vernalisation treatments of two varieties of rice is reflected in an increase in grain yield. This increase in the yield is also accompanied by an increase in the percentage of grain setting. These observations indicate the possibilities of increasing the grain yield of rice by vernalisation treatments. It is, however, to be noted that the response is of varietal in nature. Vernalisation treatments resulted acceleration of flowering in all the varieties except *Jhanji*. In *Bhasamanik* earliness is induced either by short days (Sircar, 1946) or by pre-sowing low temperature (Table XII). In a previous work (Sircar, 1944) it was reported that chilling (3°C. to 6°C.) for 3 weeks produced no significant earliness while a significant earliness of about a week noted in this work is possibly due to short periods; 5 to 10 days of chilling. Ghosh (1948) has also reported that pre-sowing low temperature treatment of seeds of other varieties of paddy for duration of 15 to 25 days resulted increased tillering and delay in flowering. From these results conclusions are that low temperature stimulation of seeds leads to increased vegetative growth as indicated by tillering and height, while its effect on acceleration of flowering is manifested only in treatments of short duration. Similar effects of low temperature on an increase in chlorophyll development of the leaves of young seedlings, a greater output of tillers, a higher percentage of culm to tiller and a greater flush of ear emergence but without an acceleration of flowering of Indian varieties of wheat have been reported by Kar (1943). It appears that in the tropics low temperature stimulation is not an obligatory factor for flowering but its influence on increased vegetative growth is maintained in the Indian varieties of wheat and rice (Sircar, 1948).

A remarkable influence of short days on the acceleration of flowering is noted in the winter varieties of *Rupsail* and *Patnai*; in these cases the effect of low temperature has not been studied. Flowering duration of *Rupsail* has been reduced from 133 to 47 days. So far as the authors are aware, the flowering of winter varieties of rice within such a short period has not been reported previously. Alam (1940-41) has noted that 60 days is the minimum period for the flowering of all varieties of rice. Hector (1936) has also noted that the minimum flowering duration of rice is 60 days. In *Patnai* the flowering duration has been reduced from 136 to 79 days. Such a reduction in the flowering duration has only been noticed in the main shoot which received the photoperiodic exposure, while in the tillers, first and second, in *Rupsail* the flowering was progressively delayed and in the remaining tillers flowering took place at about the same time as control. With the acceleration of flowering the vegetative growth of the main shoot is considerably reduced as only 10 to 12 leaves were produced against 16 to 20 in the control. These results show the effect of short days on the acceleration of flowering by the curtailment of vegetative growth.

The interesting observation on the main shoot flowering within a very short time needs further work to throw light on the nature of photoperiodic perception in rice. A hormonal theory of plant development has been suggested by Cailahjan (1936) and Hamner and Bonner (1938) in their investigation on photoperiodic response of different plants (Whyte, 1947). The theory expressed by them is that the photoperiodic induction is the result of the action of the flower hormone or the 'florigen' produced in the leaves during a short exposure of the plant to light conditions which hasten flowering. Cailahjan has further shown that the growing point when supplied with a sufficient quantity of the hormone quickly forms flower buds and flowers. In plants having a high capacity of regenerating new growing points, as for example, hemp and perilla, these newly formed growing points receive an insufficient quantity of the flowering hormone since a larger part of it has already gone into the earlier formed shoot. Consequently the plant on beginning to flower passes again to vegetative growth. Evidence of the failure of flowering due to the movement of insufficient quantity of the flowering hormone has also been shown by Cailahjan in Chrysanthemum. In this plant even number of leaves was exposed to short days of 10 hours and odd numbers to long natural days. The buds appeared first in the axils whose leaves received short days, while the buds developed later at the axils of the normal day light leaves, which under normal day light conditions do not develop. The buds developed into flowers only in those cases which received short day, while the buds at the axils of the leaves receiving natural day length did not open. In view of these findings an explanation for the variation in the flowering times of the main shoot and tillers of rice varieties may be suggested. It appears that the flowering behaviour of the main shoot and tillers is related to the distribution of the flower forming hormone in the growing points. Hormone synthesised in the leaves exposed to short days was first translocated to the growing points of the main shoot and induced flowering and a portion of it accumulated at the growing points of the buds formed at the time of photoperiodic exposure. When these buds grew into tillers accumulated hormone caused them flowering, while the tiller buds formed after the period of exposure received very little quantity of the hormone, consequently the flowering of these tillers was as late as the control. Thus it seems the distribution and concentration of the flowering hormone is the cause of the variation in the flowering of the main shoot and tillers of these two varieties. The whole question requires further investigation on the nature of the growing point at the time of photoperiodic exposure.

Summary.

Pot culture experiments on vernalisation and photoperiodic response of three varieties of winter rice, *Rupsail*, *Patnai* and *Bhasamanik*, and of two summer varieties, *Jhanji* and *Bhutmari*, have been described. The treatments adopted are: (i) short day exposure of seedlings for varying periods, (ii) pre-sowing low temperature treatment of seeds for different periods, (iii) pre-sowing low temperature followed by short day treatment of the seedlings. Effects of these treatments on tillering, height, leaf number, ear emergence and number, grain setting and weight, and total grain yield have been studied.

Low temperature and low temperature followed by short days increased the tillering rate, height and the number of ear bearing tillers in *Bhasamanik* and this was accompanied by increased grain yield.

By short day exposure an indication of increased number of ear bearing tillers and grain yield was noticed in *Jhanji*, while the ear number decreased in *Bhutmari*, but the yield differences between the control and the treated plants are little.

Although tillering and the number of ears increased in *Patnai* by short day treatment, the grain yield as compared with the control decreased because of the reduction in the number of grains set per ear.

Between short day and control plants of *Rupsail*, there was not much difference in tillering, ear number and total grain yield.

Vernalisation treatments resulted acceleration of flowering of all the varieties except *Jhanji*. Response to the treatments is a varietal character.

A considerable reduction in the flowering duration of the main shoot of *Rupsail* from 133 to 47 days and of *Patnai* from 136 to 79 days was noticed. This was accompanied by a reduction in leaf and spikelet numbers and grain yield of the main shoot. After photoperiodic exposure the main shoots of these two varieties flowered much earlier than other tillers and a varying degree of earliness in the first and second tillers of *Rupsail* noted.

An attempt to explain the cause of this variation in the flowering of the tillers on the distribution and concentration of flowering hormone has been made.

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Description of Plates VII and VIII.

Illustrating Dr. S. M. Sircar and Mr. B. Parija's paper on 'Vernalisation and photoperiodic response in five varieties of rice'.

Plate VII.

Fig. 1.—Plants after transplantation kept in cemented tanks provided with stoppered outlets for maintaining constant water level.

Fig. 2.—Flowering of *Rupsail* in seed beds within six weeks of short day treatment.

Plate VIII.

Fig. 3.—Effects of the treatments on height and flowering of the tillers of *Rupsail* after the seedlings were transplanted.

Fig. 4.—Increase in height of *Bhasamanik* by the combined effect of low temperature and short days.

Fig. 5.—Effects of the treatments on the production of tillers in *Bhutmari*.

Fig. 1.

Fig. 2.

FIG. 3.

FIG. 4.

FIG. 5.