STUDIES IN THE PHYSIOLOGY OF RICE.

III. Vernalisation by Short Days.

(A preliminary report.)

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Introduction.

The scope of vernalisation in Indian agriculture has been discussed by Sircar (1939) and Sen (1940). Its practical utility for rice is two-fold. First, by inducing earlier maturity the crop might escape flood and other adverse conditions. Secondly, earlier harvesting would leave sufficient time for the preparation of fields for the crops following in rotation. Considering this, it is surprising that sufficient work to explore the possibilities of applying this technique to rice has not yet been done. Alam (1940) has noted that the pre-treatment of rice seeds by low temperature does not induce any change in the time and period of flowering, but there is an indication of increased grain yield due to better tillering of individual plants. It has been reported by Hedayetullah and Sen (1941) that a summer variety, *Dharial*, responds to high temperature treatment by inducing earliness of 12 days without any adverse effect on grain yield. But, as far as vernalisation by high temperature is concerned, there are certain practical difficulties for its application to rice. The germinating seeds when exposed to high temperature rapidly grow into seedlings involving difficulties of transportation. Further, the application of a constant high temperature to a large number of seedlings is not feasible for the cultivators of rice in India. While the method of vernalisation adopted in the present investigation by exposing the seedlings to short days is applicable to the varieties of rice which are normally transplanted because there is no practical difficulty for rice-growers to apply short day treatment in seed beds. A brief summary of the results obtained in this work has been published elsewhere (Sircar 1944).

A clue to this method has been obtained from recent investigations on the theory of photoperiodism. Eghis, Rasumov, Ljubimenko and others (Whyte, 1939) have noted that short day plants grown in short days for the first 10–20 days and then in long days flowered earlier than the plant grown in long days throughout. This phenomenon has been termed the photoperiodic after-effect or photoperiodic induction. An acceleration of flowering by treatment of seedlings to exposures of different photoperiods has become known, after Cailahjan (1933), as 'vernalisation by light'. Purvis and Gregory (1937) have shown reduction of vegetative growth and acceleration of flowering in *Petkus winter* rye by preliminary treatment of short days of 10 hours and this effect they have called vernalisation by short days.

Previous investigations on photoperiodism of rice by Hara (1930), Fuke (1931), Alam (1940), Pan (1936), Sircar (1942), Sircar and Parija (1945), and Kar and Adhikary (1945) have demonstrated the effectiveness of short days in inducing earliness in local varieties, but so far as the author is aware, the agricultural possibilities of the phenomenon depending on the effectiveness of photoperiodic treatment of the seedlings before transplantation have not yet been studied. The present investigation was undertaken with a view to test how far the application of short days in the seed bed would induce vernalisation or acceleration of flowering of rice. It was also intended to demonstrate the earliness induced by continuing the treatment after transplantation. The effects of these treatments on vegetative growth and grain yield were determined.

Material and Method.

A pure strain of winter rice, variety *Bhasamanik*, was used in this investigation. It is a high yielding variety and has a very wide range of adaptability in Bengal. After sterilisation with 0·2 per cent formalin 100 seeds were sown in earthenware pots, 15″×5″, on May 8, 1941. These pots filled with a mixture of cow dung and garden soil in the proportion of 1 : 8 were used as seed beds. Germination was 100 per cent and in the course of a week the first two leaves came out. One week after sowing, short days of 6, 8 and 10 hours were given to the seedlings in the seed bed for 2, 3, 4, 5 and 6 weeks. For giving short days of 6, 8 and 10 hours the seedlings were exposed to the sun from 8 a.m. to 2, 4 and 6 p.m. respectively and for the rest of the day they were removed to a well-ventilated light-proof house. After the treatment for the required number of weeks was over in a particular set, then these seed beds were left exposed to natural day length for the remaining period for transplantation with the control so that all the seedlings were transplanted on the same day, June 26. In order to study the effect of prolonging the light treatment another experiment was performed in which these photoperiods were given to seedlings in seed beds for six weeks and continued after transplantation until ear emergence was noticed in the individual plants. There was one control seed bed exposed all through to natural day light. All other conditions except light were kept as far as practicable identical in all the treatments. Two seedlings spaced 5″ were transplanted in one pot, 10″×10″, filled with the mixture of cow dung and garden soil. Nineteen treatments including the control with 15 pots in each were employed; in all there were 285 pots in this investigation. Data for tillering, ear emergence and grain yield were collected from one plant per pot.

Experimental Results.

Experiment I.—Seed bed treatment.

Tillering.—In this experiment short days of 6, 8 and 10 hours were applied to one-week old seedlings in the seed bed when the seasonal day length was approximately 13 hours. In order to investigate the effect of these treatments on subsequent vegetative growth of the plants tiller measurements were taken at fortnightly intervals. The first count was made a fortnight after the seedlings had been transplanted in pots and the last measurement was taken when the ear emergence was complete. The data presented in Table I would show that the application of these photoperiods in the seed bed does not make any difference in the vegetative growth of the plant as indicated by tiller numbers throughout the entire vegetative period. It is, however, interesting to note that the treatments have an effect on the number of tillers bearing ears. Tiller counts made on the dates, one before ear emergence (September 24) and the other after ear emergence was complete would show that in the photoperiods of 8 and 10 hrs. for 5 and 6 weeks most of the tillers live up to maturity and bear ears while in the control and other treatments some of the later formed tillers die; consequently the number of ear-bearing tillers falls. Table I would show that the treatments 6 hrs. for 2, 3, 4, 5 and 6 weeks, 8 hrs. for 2, 3 and 4 weeks and 10 hrs. for 2 and 3 weeks may be classified into one group and the treatments 8 hrs. for 5 and 6 weeks and 10 hrs. for 4, 5 and 6 weeks into another.

TABLE I.

Tiller No. (average of 15 plants).

Treatments.	9-7-41	24-7-41	9-8-41	24-8-41	9-9-41	24-9-41	Ear-bearing tillers.
Control	2·6	3·3	4·1	6·1	7·3	7·6	6·0
10 hours photoperiod for							
2 weeks	1·7	2·1	3·0	4·2	5·3	6·2	5·7
3 ,, ...	1·9	2·5	3·4	4·4	5·4	6·0	5·5
4 ,, ...	1·7	2·6	3·6	4·7	5·7	6·2	6·0
5 ,, ...	1·6	2·1	2·9	4·2	5·2	5·6	5·6
6 ,, ...	1·8	2·6	3·6	4·6	5·6	6·2	5·9
8 hours photoperiod for							
2 weeks	2·1	2·9	4·3	5·8	7·2	8·2	7·1
3 ,, ...	2·6	3·6	4·8	6·4	7·8	8·9	7·8
4 ,, ...	2·9	3·6	4·5	5·7	6·7	7·2	6·2
5 ,, ...	1·7	2·2	3·0	4·0	5·1	5·8	5·6
6 ,, ...	1·6	2·1	3·1	4·2	5·5	6·3	6·1
6 hours photoperiod for							
2 weeks	2·3	3·0	4·3	5·7	6·9	7·8	6·3
3 ,, ...	2·5	3·0	4·3	5·4	6·8	7·8	6·8
4 ,, ...	2·1	2·3	3·1	4·2	5·5	6·0	5·1
5 ,, ...	2·6	3·2	4·3	5·5	6·8	8·0	6·8
6 ,, ...	2·5	3·0	4·0	5·4	6·7	7·4	5·8

Ear emergence.—The criterion of ear emergence was taken as the exsertion of the inflorescence through the last leaf (flag leaf) sheath of the main shoot. Observations were made each day at about 8 a.m. Data for ear emergence are presented in Table II.

TABLE II.

Treatments.	No. of days from sowing to earing (average of 15 plants).	Earliness as compared with the control.
Control	165	
10 hours photoperiod for 2 weeks	156·3	8·7
,, ,, 3 ,, ...	156·5	8·5
,, ,, 4 ,, ...	152·3	12·7
,, ,, 5 ,, ...	154·7	10·3
,, ,, 6 ,, ...	152·5	12·5
8 hours photoperiod for 2 weeks	158·7	6·3
,, ,, 3 ,, ...	155·7	9·3
,, ,, 4 ,, ...	154·4	10·6
,, ,, 5 ,, ...	154·7	10·3
,, ,, 6 ,, ...	155	10
6 hours photoperiod for 2 weeks	164·2	0·8
,, ,, 3 ,, ...	164·2	0·8
,, ,, 4 ,, ...	162·4	2·6
,, ,, 5 ,, ...	159·1	5·9
,, ,, 6 ,, ...	157·1	7·9

It will be seen that with the same date of sowing and transplantation there is a marked earliness in different treatments. Eight and 10 hours are more effective in inducing earliness than 6 hours. In order to test the significance of the treatments the data are subjected to the analysis of variance. The following table shows that between treatments variance is highly significant indicating earlier ear emergence in the treatments. Photoperiods of 10 hrs. for 4 and 6 weeks give the earliest ear emergence.

TABLE III.

Analysis of Variance of number of days for ear emergence.

Sources of variation.	Degrees of freedom.	Sum of squares.	Variance.	Ratio.
Between treatments	15	3610·66	240·71	*75·46
Within treatments	224	715·07	3·19	....
TOTAL ..	239	4325·73	....	....

* Indicates significance at 1% level.

Grain yield.—It has been reported by Bell (1936) that vernalisation treatment stimulates earlier production of tillers in wheat, but shortening of vegetative phase prevents normal tiller development and the number of surviving ears at harvest is less than the control. From this he expresses the opinion that vernalisation methods may lead to a reduction in the yield of cereals. In a later communication (1937) he has noted that gross yields per plot were unaffected but there was a general increase in the yield per plant by low temperature treatment. Despite the advantages of early flowering, the technique of vernalisation that may decrease the yield will not have sufficient agricultural importance for the cultivation of rice in India, where the yield as compared with other rice-growing countries is very low. In order to investigate this a comparison of the yield of grains was made and the data with the relevant statistical analysis are presented in Tables IV and V.

TABLE IV.

Average yield in grams per plant.

Treatments.	Duration in weeks.				
	2	3	4	5	6
10 hours photoperiod ..	13·13	13·70	14·00	13·33	14·40
8 hours "	12·93	13·13	14·87	13·60	15·24
6 hours "	14·13	15·53	13·63	11·93	13·47
Control		12·7			
Critical difference at 5% level		1·76			

TABLE V.

Analysis of Variance of grain yield.

Sources of variation.	Degrees of freedom.	Sum of squares.	Variance.	Ratio.
Between treatments	15	190·47	12·70	*2·09
Within treatments	224	1360·14	6·07	....
TOTAL ..	239	1550·61	6·49	....

* Indicates significance at 5% level.

Although higher yield is noticed in some of the treatments, the statistical analysis reveals that only three treatments are significantly different from the control. The critical difference at 5% level being 1·76, it may be noted that the treatments 8 hrs. for 4 and 6 weeks and 6 hrs. for 3 weeks induce a just significant increase in yield. From these results it appears that the method of vernalisation adopted in the present investigation does not reduce the grain yield; on the contrary there is an indication of increased grain yield.

Experiment II.—Prolonged treatment.

Tillering.—This experiment was designed to investigate the effect of prolonged treatment on tillering, earliness and grain yield. Seedlings after receiving photoperiods of 6, 8 and 10 hours for 6 weeks in the seed bed were transplanted in pots, then they were exposed further to the same photoperiods until heading. Tiller measurements of the plants, taken on the same dates as in Experiment I, show that the prolonged photoperiods of 8 and 10 hours have stimulated tillering while 6 hours has caused a fall in tiller number (Table VI). This effect becomes noticeable after continuing the treatment for about a month. As the treatments are prolonged further, more tillers are formed in 8 and 10 hours photoperiods than in control and 6 hours photoperiod. It is also noticed that most of the tillers of these treatments bear ears while in the control and 6 hours light period a reduction in the number of fertile tillers takes place. A comparison of these results with those of Experiment I would show that prolonged photoperiods of 8 and 10 hours increase tillering and the number of ear-bearing tillers.

TABLE VI.

Tiller No. (average of 15 plants).

Treatments.	9-7-41	24-7-41	9-8-41	24-8-41	9-9-41	24-9-41	Ear-bearing tillers.
Control	2·6	3·3	4·1	6·1	7·3	7·6	6·0
10 hours photoperiod until earing	3·0	4·1	5·5	7·0	8·6	9·7	9·0
8 hours photoperiod until earing	3·1	4·2	5·6	7·5	9·5	10·5	10·0
6 hours photoperiod until earing	1·9	2·6	3·5	4·7	5·8	7·0	4·9

Ear emergence.—Acceleration of earing in 6, 8 and 10 hours is so obvious that without statistical analysis it may be concluded that earliness in ear emergence is induced in each photoperiod (Table VII). Although plants treated for 6 hours

TABLE VII.

Treatments.	No. of days from sowing to earing (average of 15 plants).	Earliness as compared with the control.	Grain yield in grams (average of 15 plants).
Control	165	....	12·7
10 hours photoperiod until earing ..	138·5	26·5	*15·5
8 hours photoperiod until earing ..	140	25	*17·7
6 hours photoperiod until earing ..	137	28	10·4
		Critical difference	2·43

* Indicates significance at 5% level.

flowered earlier than the others, the treatment produced some adverse effects on vegetative growth as indicated by tillering, the number of ears and grain formation. Some of the tillers in this treatment did not produce any ear or in some cases ears were formed but grains did not set and the whole ear was empty.

Grain yield.—The data presented in Table VII would show that as compared with the control the yield of grains in 10 and 8 hours photoperiod had increased while 6 hours photoperiod had depressed it. In this respect 8 hours photoperiod is found to be superior to 10 hours. Reduction in the yield of 6 hours plants is due to the fact that this treatment resulted in a poor vegetative growth, smaller number of ear-bearing tillers and a failure of grain formation.

TABLE VIII.

Analysis of Variance of grain yield.

Sources of variation.	Degrees of freedom.	Sum of squares.	Variance.	Ratio.
Between treatments	3	462·15	154·05	*13·97
Within treatments	56	617·95	11·03	....
TOTAL ..	59	1080·10	18·31	....

* Indicates significance at 5% level.

The statistical analysis shows (Tables VII and VIII) that this effect on increasing the grain yield is significant.

DISCUSSION.

From the results of this investigation two features of agricultural importance are noteworthy. Firstly, application of short photoperiods of 6, 8 and 10 hours induces a significant earliness in both experiments. The degree of earliness is dependent on the duration of the treatment, greatest earliness being noticed in the prolonged treatment. Although greater earliness is observed by continuing the treatment, the application of the method in field practices is possible only by the treatment of seedlings in seed bed. Rice seedlings are usually transplanted to fields after 6 to 7 weeks from the date of sowing; accordingly the photoperiodic treatments were applied to one-week old seedlings for 6 weeks in the seed bed and the seedlings transplanted to pots. This resulted in a maximum earliness of 10 and 12 days in photoperiods of 8 and 10 hours respectively.

Purvis and Gregory (1937) have shown that an exposure to short days of 10 hours for 6 weeks duration was optimal for early flowering in *Petkus winter rye* and that more prolonged treatment tended to reverse this effect. In the experiments with rice a different picture is noticed. An exposure of seedlings for 6 weeks induces an earliness of 12 days (Table II); acceleration of earing was 20 days in the treatment commenced when the seedlings were 6 weeks old and continued until heading (Sircar 1942), an earliness of 26 days was noticed in the treatment begun in the seed bed and prolonged until ear emergence (Table VII). These results show that the effect of short days in the acceleration of flowering in rice is not reversed by the prolonged treatment. An increase in shortening the vegetative period by an increase in the duration of the treatment indicates that the photoperiodic effect in this variety of rice is of a quantitative nature.

The formative effect of short days is thus exhibited in this variety and according to Garner and Allard's terminology it is a short day plant. In recent years the classification of plants into short and long day types has been questioned by Whyte and Oljhovikov (1939*a* and *b*), as investigations on wheat, millet, rye and other cereals have shown that short day or dark requirements of plants is inherent in the so-called short day plants not throughout their lifetime but only during a definite period of their development. 'After this period has been completed long day has no longer a retardative effect on the eventual time of flowering; on the contrary, short photoperiods tend to retard subsequent development.' (Whyte and Oljhovikov, 1939*a*.) It has been concluded that so-called short day plants are not typical short day plants but may be described as short day→long day plants. In the experiment of prolonged treatments rice seedlings were exposed all through to short days until heading and there was no succession of short and long days. The acceleration of earing was maximum and the grain yield increased under this condition (Table VII). In view of these results it appears that this variety of rice completes its growth and developmental phases under short day conditions and is a typical short day plant.

The other interesting result of this investigation is the possibility of increasing the yield by short days. A significant increase in the yield has been noted in 8 hours photoperiod for 4 and 6 weeks and in the prolonged treatment of 8 and 10 hours photoperiod. Bell (1936) has observed that the acceleration of earing in wheat by low temperature treatment is reflected in the curtailment of vegetative growth and the total number of tillers is reduced. Hence he considered that this may reduce the yield. It has been reported by Hard-Karrer (1933) that by decreasing the length of light period large vegetative plants are produced with increased tillering of wheat but reduced grain yield and retarded earing. The effect of vernalisation by short days in this variety of rice is different. It induces earliness with an additional advantage of increasing the grain yield. Its beneficial effect is further noticed in the increased number of ear-bearing tillers. Under normal conditions all the tillers of a rice plant do not survive up to maturity; later formed ones die away without forming ears. The results of this investigation show that in 8 and 10 hours photoperiods almost all the tillers live up to maturity and bear ears (Tables I and VI). Further work on the possible use of these results in field practices is in progress at this laboratory under the auspices of the Imperial Council of Agricultural Research, New Delhi.

Summary.

1. The effects of short days of 6, 8 and 10 hours on growth, acceleration of flowering and grain yield of one variety of winter rice, *Bhasamanik*, have been studied in pot culture experiments.

2. Short days were applied to one-week old seedlings for varying periods in the seed bed and at the end of 6 weeks seedlings were transplanted in pots. In another experiment short days were prolonged after transplantation until ear emergence.

3. Both treatments result in acceleration of flowering. The degree of earliness increases with the duration of treatment showing that the effect of short days is of a quantitative nature.

4. Acceleration of flowering is not reflected in the curtailment of vegetative growth, on the contrary 8 and 10 hours photoperiod for prolonged duration increases tiller number.

5. Eight and 10 hours photoperiods longer than 4 weeks duration enhance the number of tillers bearing ears.

6. The yield of the grains is increased by the seed bed treatments of 8 hours for 4 and 6 weeks and of 8 and 10 hours in prolonged photoperiods.

7. On the basis of the experimental data presented a method of vernalisation of rice by short day treatment of seedlings before transplantation is suggested.

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