STUDIES ON THE PHYSIOLOGY OF RICE

XI. Vernalization and Devernalization of Winter and Summer Varieties

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Introduction

Previous results from this laboratory (Sircar, 1948; Sircar and Parija, 1949; Sircar and Ghosh, 1954) indicate that the relation of germination temperature of rice and subsequent photoperiodic exposure is by no means simple. High temperature germination of summer varieties is conducive to earliness while winter varieties appeared to be temperature neutral (i.e. no effect of temperature on acceleration).

As regards the photoperiodic behaviour the main shoots of the winter varieties are very sensitive to short days but for the summer varieties short days have retarding effect and even annul the high temperature acceleration. The effect of low temperature is enhanced tiller production in winter varieties and subsequent short photoperiods induce earliness in the main shoot as well as in the tillers indicating the influence of low temperature at some stage of the development of the so-called temperature neutral winter varieties.

In rye an extremely interesting picture has been presented by Purvis and Gregory (1952) and Friend and Gregory (1953). The optimum temperature of vernalization of winter rye is about 2°–4°C. and with increase of duration vernalization effect not only increases but also it becomes stable (i.e. not to be easily devernalized at higher temperature). Friend and Gregory have shown further that higher temperature which is generally used for devernalization does accelerate flowering when it is applied for long duration after treating the seeds with low temperature.

Thus a consideration of the phenomenon of vernalization and devernalization of rye seeds emphasizes the desirability of a critical study of the temperature relations of rice seeds. Further to establish the relation between vernalization and photoperiodism in rice an extensive survey of the conditions using a wide range of temperatures and short day length is required. In the present investigation the problem has been approached by using a combination of different temperatures of germination and day length.

The effect of field temperature on flowering of a winter variety has also been studied for which sowing dates in summer and winter were used. These results are also discussed in the light of the scheme suggested by Purvis and Gregory for flowering in rye.

Materials and Methods

This work was carried out with rice var. *Rupsail* (winter variety) and *Dhairal* (summer variety) supplied by the State Agricultural Research Station, Chinsura, West Bengal. Summer varieties are normally sown in April-May and harvested in August-September of the same year, while winter varieties are sown in seed beds in June, transplanted in July and harvested in the following December-January. The method of vernalization used is essentially the same as that described by Purvis and Gregory (1952). The air dry grains of rice were treated with Spergon (tetrachloroparabenzoquinol) to prevent attacks of micro-organism and soaked in sterilized distilled water for 24 hours. Then they were transferred to sterilized Petri dishes and sprouted for 24 hours at 25°-26°C. in darkness. During subsequent treatment the dishes were kept at temperatures 1°-2°C., 12°C., 25°-26°C., 30°-31°C. and 37°C. Constant water content (50% of the oven dry weight of the seed) of the sprouted grain was maintained by adding sterilized water at regular intervals. At the end of the temperature treatment all the treated seeds in Petri dishes were kept at 26°C. for 24 hours for further sprouting. The better sprouted seeds were sown in pots containing well manured garden soil. The seeds of the control sets were also soaked for 24 hours and then allowed to germinate at 26°C. for 1 day before sowing. The dates for commencing the treatments were so adjusted that all the treatments had the same sowing date and same environmental conditions during the growing period.

For photoperiodic treatment plants were grown under 8 hour short days from 8 a.m. to 4 p.m. after having natural day length above 13 hours for 53 days. The short day treatment was continued for four weeks and the plants were exposed to natural day length until flowering. During short day treatment the pots were transferred daily to a well ventilated dark room from 4 p.m. to 8 a.m.

Scoring Method:

During the growing period the detailed morphological changes of shoot apices were examined under Zeiss Sterio Binocular Microscope at regular intervals. During

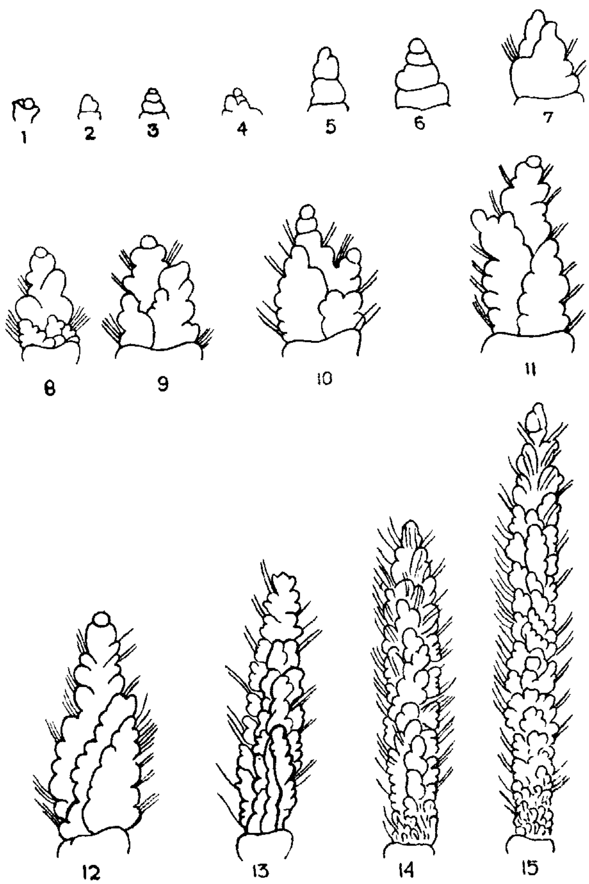

FIG. 1. Stages of the development of the shoot apex of rice var. *Rupsail*. Numbers denote the 'score'.

For explanation see the text and Table 1. Scores Nos. 1 to 15—magnification ×20.

the vegetative growth dissections were performed twice a week but after the floral initiation dissections of an average of 20 plants were made daily. To study the subsequent changes of the shoot apex during its transition from vegetative growth to flowering, the different stages of development have been carefully examined, measured and studied in several conventional units (scores). Under short day condition the rice plant after initiation of floral primordia requires approximately 22–25 days for the emergence of flower. Accordingly the stages of development of the shoot apex were divided into 25 units of scores (Figs. 1 and 2 and Table 1) and they were arranged in such a manner that each score presumably represents the daily change in the development of the shoot apex.

FIG. 2. Stages of the development of the shoot apex of rice var. *Rupsail.* Numbers denote the 'score'.

For explanation see the text and Table 1.

Scores Nos. 16–18	..	magnification ×10.
Scores Nos. 19-20	..	magnification ×5.
Scores Nos. 21-22	..	magnification ×1.
Scores Nos. 21 (*a*) and 22 (*a*)	..	magnification ×5.

EXPERIMENT 1

Vernalization and devernalization of a winter variety Rupsail

This experiment was arranged to study the effect of different temperatures during germination on growth and flowering of a winter variety. The scheme of the treatment of the germinating grains was as follows:—

(1) Continuous high or low temperature for different durations.
(2) Alternate periods of high and low temperatures for varying durations.
(3) Interposition of high or low temperature for a short duration in between two periods of low or high temperature for a longer duration.

The experiment was started on May 15, and seeds sown on June 15, 1954, in earthenware pots. Flowering was assessed by the date of ear emergence and score number. From the results presented in Table 2, the following facts are noticed.

TABLE 1

Morphological changes in the shoot apex of rice variety Rupsail

	Size in mm.	Score
Vegetative stage		
Vegetative shoot apex enclosed by hood-shaped leaf ..	..	1
Flowering stages		
Shoot apex with globular protrusion (flower primordia) from one side of it	..	2
Shoot apex having two protrusions on both sides ..	0·2	3
Protrusion on all sides	0·2	4
Elongation of the apex with primary protrusion ..	0·5	5
Increase in length and breadth of primary protrusion ..	0·6	6
Transition from primary protrusion to a number of spikelets associated with many hair-like structures ..	0·8	7
Elongation and further differentiation of the stage ..	0·9	8
Do. Do.	1·0	9
Do. Do.	1·1	10
Do. Do.	1·6	11
Do. Do.	2·0	12
Establishment of the shape of ear, ear still stiff ..	2·4	13
Increase in the length of ear, associated with grand period of extension growth of stem	3·0	14
Individual flower appears at the tip with glumes, grand period of extension growth	4·0	15
Differentiation of the individual flower from tip to base, accompanied by the elongation of the spike, grand period of extension growth	5·2	16
Do. Do.	6·0	17
Do. Do.	7·0	18
Do. Do.	13·5	19
Do. Do.	20·0	20
Grand period of elongation of ear, ear limp	82·0	21
Do. Do.	166·0	22
Emergence of the spikes from the flag leaf	171·0	23
Anthesis	..	24
Past anthesis	..	25

A continuous high temperature of germination (30°-31°C. and 37°C.) for varying durations up to 4 weeks has no direct effect on the acceleration of flower primordia over the control. These higher temperatures on the contrary delay the flowering and the delaying effect generally increases with the duration of the treatment (V_6 and V_7). Again from the Table it is evident that the scores of V_1, V_2, V_3, V_4 and V_8 are less than that of the control. Similarly a continuous low temperature (i.e. 12°C.) has no effect on the acceleration of flowering rather it delays which, however, is not statistically significant (Table 2, V_{13}–V_{16}). Effects of presowing alternate temperatures show acceleration. Thus the treatments V_{17} (2 weeks at 37°C. followed by 2 weeks at 12°C.), V_{19} (1 week at 37°C. and 1 week at 12°C.), and V_{22} (alternate days at 37°C. and 12°C. for 4 weeks) induce earliness. The acceleration of V_{17} is statistically significant. But the delaying effect of alternate temperatures on other treatments can be explained by considering that the duration of temperature is important in bringing the acceleration effect. Interposition of a different temperature for 4 days in between two periods of a continuous high or low temperature is found to have no significant acceleration (V_{25}–V_{28}).

TABLE 2

Effect of presowing temperature treatments on floral initiation of Rupsail. *Sowing date 15-6-1954*

Treatments	Number of days for ear emergence on the main shoot (average of 10–14 plants)	Score number on 140th day of sowing (average of 10 plants)	Number of spikelets per ear Fertile/Sterile
V_c control (soaked and sprouted for 24 hrs. at 26°C.)	150·5 ± 1·7	14	100·2/16·2
V_1, 37°C. for 4 weeks	..	6	..
V_2, 37°C. for 3 weeks	..	7	..
V_3, 37°C. for 2 weeks	..	7	..
V_4, 37°C. for 1 week	..	7	..
V_5, 30°-31°C. for 4 weeks ..	..	7	..
V_6, 30°-31°C. for 3 weeks ..	163·5 ± 4·17	..	83·2/9·7
V_7, 30°-31°C. for 2 weeks ..	152·6 ± 1·2	..	86·7/10·5
V_8, 30°-31°C. for 1 week ..	..	12	..
V_9, 25°-26°C. for 4 weeks ..	..	7	..
V_{10}, 25°-26°C. for 3 weeks ..	..	8	..
V_{11}, 25°-26°C. for 2 weeks ..	157·6 ± 1·5	..	85·5/12·5
V_{12}, 25°-26°C. for 1 week ..	151·8 ± 1·6	..	88·2/7·5
V_{13}, 12°C. for 4 weeks ..	..	10	..
V_{14}, 12°C. for 3 weeks ..	154·5 ± 1·5	..	70·2/14·2
V_{15}, 12°C. for 2 weeks ..	154·5 ± 1·2	..	72·7/17·1
V_{16}, 12°C. for 1 week ..	..	10	..
V_{17}, 2 weeks at 37°C. followed by 2 weeks at 12°C.	136·0 ± 1·3	..	62·5/19·1
V_{18}, 2 weeks at 12°C. followed by 2 weeks at 37°C.	..	12	..
V_{19}, 1 week at 37°C. followed by 1 week at 12°C.	144·0 ± 2·4	..	70·9/16·2
V_{20}, 1 week at 12°C. followed by 1 week at 37°C.	..	12	..
V_{21}, alternate day at 37°C. followed by 12°C. for 4 weeks	..	·16	..
V_{22}, alternate day at 37°C. followed by 12°C. for 3 weeks ..	147·4 ± 1·2	..	68·8/14·3
V_{23}, alternate day at 37°C. followed by 12°C. for 2 weeks ..	152·6 ± 1·1	..	76·5/7·5
V_{24}, alternate day at 37°C. followed by 12°C. for 1 week	153·2 ± 1·4	..	79·5/10·6
V_{25}, 1 week at 12°C. followed by 4 days at 37°C. followed by 1 week at 12°C.	150·4 ± 0·85	..	75·8/9·5
V_{26}, 1 week at 12°C. followed by 4 days at 26°C. followed by 1 week at 12°C.	..	11	..
V_{27}, 1 week at 37°C. followed by 4 days at 12°C. followed by 1 week at 37°C.	..	14	..
V_{28}, 1 week at 26°C. followed by 4 days at 12°C. followed by 1 week at 26°C.	150·4 ± 0·85	..	75·8/9·5

EXPERIMENT 2

Effect of sowing time on the flowering of temperature treated seeds of Rupsail

The experiment was carried out in winter at the end of normal harvesting season of winter rice. It commenced on November 25 and seeds after treatments were sown on December 25, 1954, in earthen pots containing well manured garden soil and exposed to natural day length (short days, varying from 10 hrs. 45 mins. and field temperature from 18°–24°C.).

The plants from different treatments were dissected on April 21, 1955 (i.e. after 116 days of sowing). The developmental stages of the shoot apex were denoted by scores (Table 3). The number of replicates for each treatment has been shown in brackets. Low temperature of the field induced slow growth rate of the plant and did not favour grain formation. The number of spikelets per ear was also reduced. Acceleration of flowering was not recorded, on the contrary delay was apparent at high temperature. By treatments with alternate temperatures for 3 weeks (S_{13} in Table 3) which caused earliness in the plants sown in normal rice season (Table 2, V_{22}) the score number was much advanced in comparison to other treatments.

TABLE 3

Effect of sowing time on floral initiation of Rupsail. *Date of sowing on 25-12-1954, after different temperature treatments*

Treatments	Score number
S(c), control	21 (18)
S_1, 37°C. for 4 weeks	4 (10)
S_2, 37°C. for 3 weeks	19 (10)
S_3, 37°C. for 1 week	17 (10)
S_4, 26°C. for 4 weeks	Seeds not germinated
S_5, 26°C. for 3 weeks	13 (9)
S_6, 26°C. for 1 week	15 (10)
S_7, 3°–5°C. for 4 weeks	Seeds not germinated
S_8, 3°–5°C. for 3 weeks	17 (9)
S_9, 3°–5°C. for 1 week	19 (13)
S_{10}, 2 weeks at 37°C. followed by 2 weeks at 3°–5°C.	3 (12)
S_{11}, 2 weeks at 3°–5°C. followed by 2 weeks at 37°C.	17 (11)
S_{12}, alternate day at 37°C. followed by 3°–5°C. for 4 weeks	15 (9)
S_{13}, alternate day at 37°C. followed by 3°–5°C. for 3 weeks	21 (18)

EXPERIMENT 3

Relation of short days to presowing temperature treatments of Rupsail. *Date of sowing 15-6-1954 and short day application 7-8-1954*

The significant effect of short days on winter varieties of rice is now a well established fact. The nature of this short day effect on vernalized plants was investigated in both winter and summer varieties (Sircar and Ghosh, 1954). Acceleration was noticed in the winter variety *Rupsail* by vernalization at 10°C. for 5 days followed by short days, whereas high temperature vernalization in the summer varieties was annulled by short day exposure. The present investigation was undertaken to ascertain further the effect of short photoperiods after treating the seeds with different temperatures for varying durations. After planting out the seedlings were grown in natural day length above 13 hours for 53 days. Subsequently short days of 8 hours for 4 weeks were applied. The plants were then kept in normal day length until ear emergence. The results (Table 4) indicate marked influence of short days on the acceleration of flowering but presowing low or high temperature treatment failed to induce further acceleration, on the contrary a delaying effect was noticed in some of the continuous and alternate temperature treatments. The fertility of the spikelets is reduced in the treatments inducing earliness.

TABLE 4

Presowing temperature treatments	Photoperiodic treatment after 53 days of natural day length	Number of days for ear emergence main shoot (average of 22–48 plants)	Spikelet numbers Fertile/ Sterile
V_{c_1}, soaked and sprouted at 26°C. for 24 hours	Natural daylight	$150{\cdot}5 \pm 1{\cdot}7$	100·2/16·2
V_{c_2}, soaked and sprouted at 26°C. for 24 hours	8 hours' daylight for 4 weeks	$97{\cdot}5 \pm 0{\cdot}17$	65·2/29·0
V_1, 37°C. for 4 weeks	,,	$99{\cdot}6 \pm 0{\cdot}57$	42·2/31·0
V_3, 37°C. for 2 weeks	,,	$99{\cdot}5 \pm 0{\cdot}84$	49·5/43·4
V_5, 30°-31°C. for 4 weeks	,,	$101{\cdot}2 \pm 0{\cdot}10$	50·0/23·7
V_7, 30°-31°C. for 2 weeks	,,	$98{\cdot}2 \pm 0{\cdot}11$	57·0/39·4
V_9, 25°-26°C. for 2 weeks	,,	$97{\cdot}7 \pm 0{\cdot}11$	62·5/31·2
V_{11}, 25°-26°C. for 4 weeks	,,	$97{\cdot}6 \pm 0{\cdot}11$	60·5/35·0
V_{13}, 12°C. for 4 weeks	,,	$101{\cdot}1 \pm 0{\cdot}74$	38·5/37·6
V_{15}, 12°C. for 2 weeks	,,	$101{\cdot}4 \pm 0{\cdot}50$	58·8/30·4
V_{17}, 2 weeks at 37°C. followed by 2 weeks at 12°C.	,,	$99{\cdot}2 \pm 0{\cdot}94$	34·0/28·5
V_{18}, 2 weeks at 12°C. and 2 weeks at 37°C.	,,	$97{\cdot}9 \pm 0{\cdot}74$	40·8/29·4
V_{21}, alternate days at 37°C. and 12°C. for 4 weeks	,,	$101{\cdot}4 \pm 0{\cdot}75$	40·9/29·3

EXPERIMENT 4

Vernalization and devernalization of summer variety Dhairal

It has been reported previously (cf. Sircar, 1948) that presowing high temperature accelerates flowering in summer variety, while low temperature retards flowering. In order to analyse critically the relation of germination temperature of summer variety the present experiment was planned with treatments for continuous high or low temperature and alternate high and low temperatures for varying durations. The experiment was started on February 10 and seeds sown on April 11, 1955. The date of ear emergence of the main axis was recorded and presented in Table 5. The following facts are apparent. Effects of continuous high temperatures (30°-31°C.) were acceleration of flowering when the duration of the treatment was up to 3 weeks (P_{15} and P_{16}) but above this duration temperature has a delaying effect which increases with the duration of the treatment (P_{13} and P_{14}). Similar effect was also noted by treatments at 37°C. (P_{18} and P_{19}). The low temperature (12°C.) for all durations, however, accelerates flowering which is statistically significant (P_{37}, P_{38}, P_{39}, P_{40}). Acceleration was also evident by treatments at 25°-26°C. for 4 weeks (P_{10}). On the other hand too low temperature (2°–4°C.) has a strong retarding effect on germination and left almost no replicates to assess significance on flowering (P_1–P_4).

It is interesting to note that alternate temperatures have induced earlier flowering when high temperature is preceded or followed by low temperature (P_{35}, P_{36}, P_7). These effects are also statistically significant. Similar results were also noted in the case of the winter variety *Rupsail* (Table 2). A marked acceleration of flowering by low temperature treatment is accompanied by greater number of fertile spikelets, while in the rest of the treatment the spikelet number is less than that of the control and there is no definite correlation between the number of spikelets and mean date of ear emergence.

TABLE 5

Effect of presowing temperatures on floral initiation of Dhairal. *Sowing date 11-4-1955*

Temperature treatments	Mean days of ear emergence main shoot (18–25 plants)	Number of spikelets per ear Fertile/Sterile
P_c, control (soaked and sprouted at 26°C. for 24 hours) . .	111·1 ± 1·45	85·5/11·5
P_1, $P2$, $P4$, 2°–4°C. for 6, 4, 2 weeks	Not germinated	. .
P_3, 2°–4°C. for 2 weeks (2 replicates) only	116·5	78·5/14·2
P_{37}, 12°C. for 6 weeks	105·1 ± 1·44	67·7/16·1
P_{38}, 12°C. for 4 weeks	101·0 ± 1·17	100·3/10·5
P_{39}, 12°C. for 3 weeks	101·8 ± 1·21	106·2/6·0
P_{40}, 12°C. for 2 weeks	104·1 ± 1·52	88·7/13·5
P_9, 25°-26°C. for 6 weeks	117·1 ± 1·20	72·5/8·5
P_{10}, 25°-26°C. for 4 weeks	105·1 ± 1·77	80·2/10·5
P_{11}, 25°-26°C. for 3 weeks	113·5 ± 0·88	75·6/11·2
P_{12}, 25°-26°C. for 2 weeks	108·8 ± 1·16	87·6/7·5
P_{13}, 30°-31°C. for 6 weeks	123·5 ± 0·5	82·5/14·5
P_{14}, 30°-31°C. for 4 weeks	120·3 ± 1·4	69·3/12·0
P_{15}, 30°-31°C. for 3 weeks	109·4 ± 1·32	83·3/12·4
P_{16}, 30°-31°C. for 2 weeks	104·2 ± 1·32	88·2/14·3
P_{18}, 37°C. for 4 weeks	123·2 ± 1·11	80·3/14·4
P_{19}, 37°C. for 3 weeks	119·1 ± 1·03	76·7/13·3
P_{20}, 31°C. for 2 weeks	95·5 ± 1·24	88·5/16·5
P_{21}, 4 weeks at 37°C. followed by 4 weeks at 2°–4°C. . .	122·1 ± 0·88	72·9/15·7
P_{23}, 2 weeks at 37°C. followed by 2 weeks at 2°–4°C. . .	124·5	60·3/19·3
P_{24}, 3 weeks at 30°-31°C. followed by 3 weeks at 2°–4°C.	117·2 ± 1·47	72 /12·3
P_{25}, 2 weeks at 30°-31°C. followed by 2 weeks at 2°–4°C.	118·3 ± 1·32	70·7/11·4
P_{29}, 3 weeks at 2°–4°C. followed by 3 weeks at 30°-31°C.	116·5 ± 0·5	80·3/11·5
P_{30}, 2 weeks at 2°–4°C. followed by 2 weeks at 30°-31°C.	113·3 ± 0·69	85·3/12·5
P_{35}, 3 weeks at 37°C. followed by 3 weeks at 12°C.	104·7 ± 1·73	60·1/10·2
P_{32}, 3 weeks at 37°C. followed by 3 weeks at 25°-26°C.	113·7 ± 0·41	77·5/12·6
P_{36}, 3 weeks at 30°-31°C. followed by 3 weeks at 12°C.	103·8 ± 1·6	85·2/13·2
P_{34}, 3 weeks at 30°-31°C. followed by 3 weeks at 25°-26°C.	109·3 ± 1·9	80·2/13·0
P_5, 3 weeks at 25°-26°C. followed by 3 weeks at 37°C.	120·4 ± 1·32	70·2/17·5
P_6, 3 weeks at 25°-26°C. followed by 3 weeks at 30°-31°C.	115·2 ± 0·63	67·2/19·3
P_7, 3 weeks at 12°C. followed by 3 weeks at 37°C.	99 ± 1·38	107·2/13·3

DISCUSSION

This paper provides evidence for a detail survey of temperatures of germination on flowering of winter and summer varieties of rice. Previous results with rice (cf. Sircar, 1948) indicate that hastening of flowering by varying temperature treatments is not so effective as that found in the temperate crops like rye. The winter variety of rice which was considered to be a temperature neutral plant showed a significant acceleration of flowering under exposure to alternate high and low temperatures of germination while continuous high or low temperature proved to be ineffective.

Rice is a tropical crop; it grows generally at a temperature about 27°C. to 33°C. under field conditions. The temperature near freezing point seems to have a lethal effect on rice embryo as most of the embryos were killed at 2°–4°C. and thus the percentage of germination was severely affected. This lethal effect of low temperature was more evident in the case of summer variety. Germination rate was also significantly reduced when such low temperature either preceded or followed high temperature treatment. At slightly higher level of temperature (12°C.) an acceleration of flowering of the summer variety was noticed in all the treatments, the effect increased with the increase of duration (P_{40}, P_{39}, P_{38}). At still higher temperatures 25°-26°C. and 30°-31°C. acceleration of flowering was also found but the effect was not so great as that in the case of 12°C. and generally decreased with increase of duration; thus acceleration at 30°-31°C. was found only up to 2 weeks' duration above which the effect of temperature did not show hastening. With still prolonged duration for 4–6 weeks a significant retardation was evident (P_{14} and P_{15}).

These results, however, do not agree with the previous findings of the vernalization temperature of rice which was found to be higher than the normal temperature (cf. Sircar, 1948). On the contrary, a generalization of the effect on the vernalization temperature between temperate and tropical crops can be shown in the following way: that the optimal temperature for vernalization in both temperate and tropical crops lies well below the normal temperature and the effect is extended and gradually slowed down up to the level of normal field temperature of respective regions (12°–15°C. for temperate crop and 30°-31°C. for tropical crop).

In the light of the results obtained in the experiments reported above the scheme put forward by Purvis and Gregory (1952) requires consideration.

Their revised scheme is represented below:—

$$\begin{array}{c} \qquad\qquad\qquad\qquad E \\ \qquad\qquad\qquad\qquad \uparrow \\ A \rightleftharpoons A' \longrightarrow B \rightleftharpoons C \longrightarrow D. \end{array}$$

' A represents the precursor from which a specific substance B is produced by a reaction at low temperature. The reaction $A \longrightarrow B$ consists of at least two stages, the first $A \rightleftharpoons A'$ is reversible by high temperature, so that devernalization and revernalization are possible. The second stage $A' \longrightarrow B$, however, can proceed either at normal or low temperatures. The substance B is evidently thermostable and C is produced by a reversible reaction proceeding forward in darkness (short day induction) and reversed in light. The reaction $C \longrightarrow D$ proceeds only in light. C and D may be regarded as substances responsible for flower initiation and development and these reactions occur in the terminal meristem. The substance B alternately may be converted into the substance E which favours leaf production.'

Friend and Gregory (1953) have assumed further that the postulated 'B' the end-product of the vernalization reaction increases auto-catalytically and that the rate of the reaction increases with temperature. The precursor A is present in the winter variety of rye which is practically temperature neutral variety; the thermostable substance B is assumed to be present there.

In the present study it is suggested that the precursor A may be present in the summer variety of rice which is vernalized by low temperature 12°C. (Table 5, P_{37}, P_{38}, P_{39}, P_{40}) and devernalized by supra-normal temperature (P_{29}, P_{30}). But in the case of winter rice the precursor A might have already been converted into substance A' in the mature grain and in the remaining part of the reaction B can only produce D by short day induction and in no case the low temperature has any influence on hastening of flowering (Table 2, V_{14}, V_{15}). The delaying effect of high temperature on winter variety of rice (Table 2, V_6, V_7, V_{11}) may be argued as devernalization reaction as the reaction $A \rightleftharpoons A'$ is reversible. Again by application of alternate high and low temperature such delaying effect of high temperature is annulled showing the reaction $A \rightleftharpoons A'$ may be proceeded forward (Table 2, V_{17}, V_{19}, V_{22}, V_{23}, V_{24}). It is assumed that B is produced auto-catalytically with temperature and thus the quantity B may be increased which intensifies the vernalization reaction. Such reaction may possibly be the causal factor for 14 days' acceleration of flowering in winter variety of rice under exposure to alternate high and low temperature.

Delaying effect of high temperature on winter variety is also found in the plants either sowing later or treated photoperiodically (Table 3, S_1, S_2, S_3, S_5 and Table 4, V_5) and such effect of high temperature is annulled under exposure to subsequent low temperature verifying the assumption presented in this paper.

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Summary

During germination seeds of winter and summer varieties of rice were treated with different degrees of continuous and alternate ranges of temperatures for varying duration.

In winter variety high and low temperatures show retardation of flowering while acceleration was recorded at alternate exposures of high and low temperatures. Similar results were obtained with late sowing in winter. The effect of short day induction, however, did not intensify the vernalizing reaction.

In summer variety an acceleration of flowering was noticed at subnormal temperature. The optimal degree for vernalization was 12°C. the effect of which extended and gradually slowed down up to the level of 30°-31°C. the normal field temperature of the crop. Above normal temperature (i.e. at 37°C.) a devernalization effect was found which increased with duration. Such retarding effect of high temperature was annulled under subsequent exposure to low temperature. The results have been discussed in the light of the scheme put forward by Purvis and Gregory and a generalization of the effect of temperature for vernalization of temperate and tropical crops is presumed.

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