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Vernalisation as a Method of Improving yields in Rice

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Introduction: The term vernalisation is now taken to include all the various adjustments of environmental factors to which seeds and seedlings may be subjected, with a view to hasten flowering and shorten the life cycle of plants. A shortened life-cycle, especially in the case of annual crops, has the advantage of avoiding the hazards of drought, seasonal pests and diseases. There is also the possibility, with such shortened durations, of growing varieties that would normally be incapable of growing in a particular locality. To the plant breeder, reduction of duration by vernalisation can be helpful in speeding up his breeding programme by raising a larger number of generations within a specific period.

There are a number of possible pre-treatment processes of seeds and young seedlings that are capable of shortening duration in annual crops, but for large-scale adoption under Indian agricultural conditions, the methods should obviously be such as not to need elaborate equipment. A further limitation is that the method should not shorten the life cycle at the expense of yield but should if possible be such as to improve the yield as well as hasten maturity. This paper describes certain studies made on the effects of vernalizing rice with the aim of shortening duration and improving yields as well.

Previous Work and Literature: Since the available literature on vernalisation in all its aspects has recently been summarised by Whyte (1946), Murneek and Whyte (1948) and others, it is not necessary to review it here. Certain preliminary attempts at vernalisation that were made at Coimbatore between the years 1933 to 1935 were reported as not very successful, possibly on account of too rigid an adherence to the method of "high temperature vernalisation" advocated for tropical crops by Lysenko. Vernalisation, as an agronomic measure was thought to be of little importance for Indian Agriculture, due largely to the lack of any systematic study of Indian crops under local tropical conditions, on the lines carried out for other crops in Western countries. Parthasarathy (1940) vernalized sterilized seeds of rice in darkness or continuous light at 10 to 20°C. for three weeks. Those vernalized in darkness flowered 4 to 5 days earlier than the control. In 1944, Kar found that the usual pre-sowing cold treatment followed by a post-sowing photostage of short days was able to induce a very marked earliness of 24 days in wheat and 43 days for oats. Thus a more systematic search for the right combinations of temperature, light and moisture conditions required for effective vernalisation of our main food crops is clearly necessary.

It may be desirable at this stage to explain the terms "long day" and "short-day" treatments. Plants are influenced in the course of their growth and development by many environmental factors. One of the major external factors is the length of day or the period for which plants are exposed to the action of light. This is technically known as the "photo-period". The vast majority of plants react to these photo-periods and particularly so in respect of the formation of flowers and development of fruits and seeds. Based upon the nature of their response to different photo-periods, plants are classified as "long day" and "short day" plants. "Long day" plants are those species, varieties or strains in which the flowering period is accelerated by a relatively long daily exposure to light, usually more than 12 to 14 hours (Garner and Allard, 1920). "Short-day" plants are those in which flowering is hastened by a relatively short daily exposure to light usually less than 12 hours, or by photoperiods of minimum intensity or by dark periods. There is also a third group of indeterminate plants where the flowering period is not influenced either way by the length of daily exposure to light.

One definite fact that has emerged from recent studies in India on vernalisation, is that low temperature vernalisation is not favourable for rice, (Kar and Adhikary, 1945). High temperature vernalisation on the other hand is found to hasten maturity in Rice (Parija, 1943). In Bengal, summer varieties of rice flower when the seasonal day length is above 12 hours, while winter varieties come to flower with day lengths of less than 12 hours. The influence of different day length periods on the earliness of ear emergence in rice has been studied by a number of workers, notably, Alam (1940), Sircar (1942, 1944), Kar and Adhikary (1945), Saran (1945) and Sen Gupta and Sen (1945). Kar and Adikary found that winter varieties of rice which do not respond to high temperature vernalisation, flowered earlier when subjected to short-day treatment, thus proving that short-days are essential for flowering in winter rice. In the case of summer varieties, short day treatment delays flowering, while long days hasten it (Sircar and Ghosh 1947). Perhaps the most remarkable instance of accelerated flowering in rice is that reported by Sircar and Parija (1945) in a winter variety called "*Rupsail*" where the normal flowering duration of 133 days was reduced to 47 days as a result of short-day treatment. The nature of vernalisation response is also varied, thus in another winter variety "*Bhasamanik*", earlier flowering along with increased grain yield has been noted by Sircar (1946), this increase being associated with an increase in the number of earhead bearing tillers.

Further work on wheat, rye and other cereals have led to the conclusion (Whyte and Oljhovikov, 1939) that the dark period requirement of so-called short-day plants is inherent only during a definite period of the plant's development. It is claimed that in such cases the plants should be described as short-day—long-day plants. In the case of rice, however, this conclusion does not seem to be warranted, because in the variety *Bhasamanik*, the acceleration of ear emergence was maximum and the grain yield also was increased, when the seedlings were exposed to short-days all through without any succession of short and long days (Mukherjee 1946).

The limitations attendent on hastening flowering are indicated by Pal (1948), who found after vernalisation studies carried out on nearly 150 strains of Indian wheat, that although a degree of earliness sufficient to be of agricultural importance could be induced in certain varieties by the use of vernalised seed, the number of tillers, the chief feature positively correlated with yield, was smaller in vernalised plants.

Material and methods: About 65 experiments were carried out in field and pot cultures, in the course of 1946 to 1949, in studying the

response of seven paddy varieties belonging to three duration groups, short, medium and long durations, to different photoperiodic treatments. The general method was to soak a known weight of seed for 24 hours, until incipient germination started, taking care to keep the moisture absorbed below the critical level needed for the embryo to separate the glumes and emerge outside. These soaked seeds were then subjected to the action of light or darkness as the case may be, for different periods, at the end of which they were sown in glazed pots of 10 inches diameter and height, holding 15 kilogrammes of soil, puddled to three inches from the surface. Seeds of the same variety soaked for 24 hours prior to sowing at the same time as vernalised seed served as the control for comparison. Parallel trials were carried out under field conditions also, during the seasons 1947, 1948 and 1949, to see how far the observations from pot cultures were corroborated by the field trials.

In view of the obvious practical difficulties inherent in high temperature vernalisation and also at low temperatures, the treatments were confined to photoperiodic modifications at ordinary laboratory temperatures, ranging from 27 to 29°C. Seeds receiving short day treatment were kept in total darkness all the 24 hours, for the duration of one or more weeks as the vernalisation treatment lasted. For providing long-day conditions, the soaked seeds were kept at a distance of 12 inches below three 60 watt electric bulbs from sunset till dawn and then under ordinary light for the rest of the day. This treatment also was continued for two periods, of one week and two weeks respectively.

At the end of the treatment periods, seeds were sown in glazed pots at 60 seeds per pot with two seeds in each of 30 holes, in each pot. Germination counts were taken one week after the sowing date and seedlings were subsequently thinned out at random in two stages so as to retain ten plants per pot at the adult stage. Periodical height measurements and tiller counts were also taken and at flowering time, the date of full emergence of the main tiller in all plants was recorded individually to determine the mean flowering duration of the variety under each treatment. At harvest time, the plants were cut at ground level, separated into earheads and straw and individual weights recorded, once at harvest time as fresh weight and again after two weeks drying in the sun as dry weight. The data were analysed for assessing the statistical significance or otherwise of the differences, between various treatments and varieties.

Results: The effects of pre-treatments at various stages from germination to harvest are set out below:

(a) *Germination:* In certain preliminary tests made early in 1946, it was found that germination of paddy seeds was adversely

affected when the soaked grains were kept for one or more weeks at low temperatures of 0° C. and 5° C. in darkness. These treatments were therefore omitted, and subsequent treatments were confined to ordinary temperatures. Under such conditions vernalised seeds were not appreciably poorer in germination than untreated seed: the percentage being 94·6% of the control seed viability. It was observed, however, that vernalised seeds were slightly later, by one day on the average, than control seeds in emerging from the soil.

(b) *Growth:* Plants from vernalised seed are in general somewhat shorter than those from untreated seed, during the early stages of growth, but later on, they make up the deficiency and at the adult stage they are often taller than the controls. This should be clear from the following table.

TABLE 1.

Effect of vernalisation on plant height at different stages of growth
(Expressed as percentages of control plant heights=100)

Stage of growth	Short duration varieties (100 days and less)	Medium duration varieties (150 days)	Long duration varieties (200 days and more)
30 days after sowing	72·8%	91·1%	92·6%
30–60 days after sowing	105·0%	97·4%	99·7%
60–90 ,, ,,	111·8%	106·4%	101·8%
90–120 ,, ,,	....	107·6%	105·1%

N.B.— The figures are mean values of about 90 sets of measurements made on nine varieties (three in each duration group) in the 1946–47 season.

The table shows that vernalised plants are shorter than controls to begin with, in all the three duration groups, but subsequently outstrip the controls in plant height. Thus in the short duration varieties vernalised plants are shorter in the beginning by more than 25%, but this disparity narrows down by the second month and when flowering sets in, during the third month and the plants attain their adult height, the vernalised plants are nearly 12 per cent. taller. In the medium group also, a similar trend is noticeable, but the initial disparity in height is less, being only about 10 per cent. The difference gets levelled up in the course of the next two months of growth and vernalised plants are slightly taller than controls when they are 60—90 days old. After 90 days the plants begin to flower and attain their full adult height, which is about 8 per cent. taller than in controls. A very similar trend is noticeable in the long duration group as well, though the initial and final differences are narrower here than in the other two groups.

The effects observed on other plant characters, like tillering, ear emergence, grain and straw yields are presented in Appendix I. For the sake of brevity these results, which were gathered from a number of pot and field experiments during four years, from 1946 to 1949, are not given in full, but only as the mean of four years' results, expressed as a percentage of control in each case.

Effect on Plant height [Appendix I (a)]: When considered over a number of seasons, it may be said that plant height is not increased to any marked degree by the treatments that have been tried so far. The maximum increase is only 10·7% in G.E.B. 24, under 7 days light treatment. On the otherhand it may also be noted that neither is there any marked reduction in final plant height, except, in the case of 3 weeks treatment in the dark of A.K.P. 8, where the height was depressed by nearly 18 per cent. It will be noted from Appendix I (a) that on the whole, plant height is more often improved than depressed.

The variation in varietal response to vernalisation treatments is also well shown in this table; for instance, amongst the short duration varieties themselves, Adt. 3 is apparently improved in height under all the four treatments, while P.T.B. 10 is depressed by the same four treatments. G.E.B. 24 is improved in height by three out of the four treatments, and the long duration varieties A.K.P. 5, A.K.P. 8 and M.T.U. 7 all appear to be somewhat improved by vernalisation.

Effect on Tillering [Appendix I (b)]: It will be noted that in tillering too, there are marked differences between varieties in response to vernalisation. In some varieties and particularly in P.T.B. 10, tillering is apparently reduced by vernalisation, but in the other varieties, such as G.E.B. 24 for instance, tillering is distinctly improved by such treatments. The table 2 given below would also serve to illustrate this point.

TABLE 2.

Effect of vernalisation upon tillering in paddy varieties.

Varieties	1946			1947			1948		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Adt. 3	1·67	1·66	100·6%	1·67	1·66	100·6%	2·64	2·23	118·4%
P.T.B. 10	1·20	1·55	77·4%	1·20	1·55	77·4%	2·23	2·75	81·2%
Co. 21	1·63	1·63	100·0%	1·63	1·64	99·4%	3·79	4·20	90·2%
G.E.B. 24	1·89	1·50	126·6%	...	...	...	3·16	2·15	146·9%
A.K.P. 5	2·04	1·35	151·1%	...	...	...	1·64	1·84	89·2%
A.K.P. 8	...	...	...	2·55	2·12	120·3%	2·78	2·25	123·5%
M.T.U. 7	1·60	1·59	100·6%	3·29	2·86	115·0%	3·14	3·34	94·0%

* (a) Vernalised; (b) Control; (c) % on control = 100.

Effect on earhead emergence: The maximum earliness that was induced in earhead emergence by means of photoperiodic treatments was 23 days in the variety A.K.P. 8, after vernalisation in the dark for 22 days. It was found that in this feature too, certain varieties were more responsive than others. Thus in Adt. 3, G.E.B. 24 and in A.K.P. 5, the maximum earliness was obtained after long-day treatments for 14 days (see Appendix I (c) reproduced below as Table 3), while other varieties like A.K.P. 8 showed the maximum response after short-day treatment. It was also noted that where flowering was very much hastened as in the case of A.K.P. 8, after three weeks of short-day treatment, other attributes such as tillering and grain yield were also very much less than in untreated controls.

TABLE 3.

Effect of vernalisation of earhead emergence in Rice

(Summary of results of 1946 to 1949–expressed as mean percentages on control=100.)

Varieties	Vernalisation treatments					Remarks.
	D. 22.	D. 14.	D. 7.	L. 7.	L. 14.	
Adt. 3		98·1	105·2	94·5	94·5	Except in A.K.P. 8, under dark day treatment for 22 days, where flowering was hastened by nearly 20%, flowering response is not improved by more than 7% by any of the treatments in this series of experiments.
P.T.B. 10		98·9	100·0	96·9	96·4	
Co. 21		97·1	96·6	97·2	97·0	
G.E.B. 24		97·2	96·9	96·8	93·9	
A.K.P. 5		98·3	99·9	98·8	95·4	
A.K.P. 8	80·9	97·8	99·1	98·9	98·4	
M.T.U. 7		101·0	97·9	97·6	98·7	

Effect on grain yields: In this feature too, varietal differences are very marked in response to vernalisation treatments [Appendix I (d)]. Three varieties, namely, G.E.B. 24, A.K.P. 5 and A.K.P. 8 appear to be very responsive and have given increased yields under all the different treatments that were tried during 1946 to 1949, while other varieties like P.T.B. 10 and M.T.U. 7, show more often a reduction in yield than an increase. It may also be observed from the table, that in general short-duration varieties such as Adt. 3, P.T.B. 10 and Co. 21 were somewhat less responsive to vernalisation than medium and long-duration varieties like G,E.B. 24 and A.K.P. 8. The variety P.T.B. 10 in particular shows hardly any improvement in either tillering or in grain yield under any of the treatments. In the case of Adt. 3, however, pretreatment under light for 14 days, seems to have induced a definite improvement in yield, as an increase of 10·5 to 61·2% was recorded in all the four seasons it was grown.

Effect on straw yields [Appendix I (e)]: A very similar trend as in grain is also noticeable in the straw yield responses of different varieties to vernalisation treatments; only the effects are somewhat less pronounced than in grain yields. Here too, the varieties G.E.B. 24 and A.K.P. 8, show consistent increases over controls. The chief difference between the effects on grain and straw is seen in the variety A.K.P. 5, where the grain yield is higher while the straw yield is lower, than controls. The other varieties do not seem to be very responsive to vernalisation in respect of straw yields.

Discussion: In the light of the results obtained so far, the possibility of utilising photoperiodic treatments as a means of primarily improving grain yields in cereal crops deserves to be explored more fully. They seem to indicate that this might be a more fruitful line of investigation than attempts to induce extra earliness in ripening. The results also indicate that even in the same crop, a good deal of varietal differences exist. It is therefore necessary to determine beforehand, which variety would respond favourably to what set of treatments, and then subject those varieties to such optimum combination of photoperiodic and other environmental factors as would help to maximise production.

The increase in grain yields noted in varieties like G.E.B. 24 and A.K.P. 8 after vernalisation is in line with the observation of Sircar (1944) that vernalisation response varies according to the nature of the variety. As mentioned before, he found that in a winter variety *Bhasamanik*, earliness with increased grain yield was obtained after vernalisation, this increase in grain yield being associated with an increase in the number of grain-bearing tillers.

In the case of cotton too, it has recently been reported (I.C.C. Ann. Rept., 1948), that vernalised seed gives significantly higher yields than untreated bulk seed, in three out of the four seasons of the trial. In this case it is of interest to note that the pre-treatment failed to achieve its immediate object of shortening the duration, but brought about some other genotypic change of a permanent nature in the strain X. 4463.

From the practical standpoint it is advisable to prefer a short-day treatment, in cases where a variety is improved in yield both by long-day and short-day treatments, since no electric equipment is needed for short-day treatments. For example, in the strain G.E.B. 24, dark day treatment for 14 days gave an average increase of 30% over control in grain yield, while from long-day treatments there was an increase of 27·3 and 33·0%. In such cases it is preferable to test the variety under large scale trials after two weeks of pre-treatment in darkness. The same is the case in the variety A.K.P. 8, where the highest average increase in grain yield of 37·9% was obtained after dark day treatment for 14 days.

Summary: Seven paddy varieties of three duration groups, short, medium and long, were studied under four types of vernalisation treatments in pot and field cultures during 1946 to 1949 and the effects observed in respect of growth flowering and yield are presented and discussed.

The possibilities of utilising this method of seed pre-treatment as a means of improving yields in rice are indicated.

The varieties, G.E.B. 24 and A.K.P. S, were found to show consistent increases in grain yield, after vernalisation treatments, and to a lesser degree in the straw yield also. It is suggested that such responsive varieties could be tried on a large scale in different rice growing centres.

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APPENDIX I.

Effects of Vernalisation on Paddy Varieties

(Summary of results of 1949 expressed as mean precentages on control = 100.

Effects. / Varieties.	Vernalisation Treatments					Remarks.
	D. 22.	D. 14.	D. 7.	L. 7.	L. 14.	
(a) Effect on plant Height						
A.D.T. 3		103·7	105·5	102·9	101·1	(1) It may be concluded that on the whole, plant height is not improved very markedly as a result of vernalisation treatments although it is improved more often than reduced.
P.T.B. 10		98·5	94·7	89·6	92·7	
Co. 21		93·3	97·8	100·7	94·2	
G.E.B. 24		106.3	110·7	106·4	95·7	
A.K.P. 5		101·3	100 8	100·2	100·5	
A.K.P. 8	32·4	101·7	101·4	104·6	101·4	(2) In A.K.P. 8 – vernalisation for D.22 reduced plant height by nearly 20%
M.T.U. 7		100·8	102·1	102·9	102·2	
(b) Effect on Tillering						
A.D.T. 3		113·5	101·2	95·6	94·5	(1) Two varieties, G.E.B. 24 and A.K.P. 8 show a definite improvement in tillering. It is not so marked in A.K.P. 5, except under L. 14 treatment.
P.T.B. 10		99·1	101·4	68·2	78·2	
Co. 21		106·2	105·1	89·8	100·0	
G.E.B. 24		108·5	116·8	107·3	125·1	(2) The 3 short duration varieties, A. D. T. 3, P. T. B. 10, Co. 21 and M.T.U. 7 do not show any improvement in tillering.
A.K.P. 5		91·4	94·1	110·3	130·3	
A.K.P. 8	85·5	105·5	105·5	112·5	137·4	(3) In the variety P.T.B. 10, tillering is depressed by vernalisation.
M.T.U. 7		94·1	79·2	76·1	90·8	
(c) Effect of flowering earliness						
A.D.T. 3		98·1	105·2	94·5	94·5	Except in A.K.P. 8, under 22 days of dark day treatment, where the flowering was hastened by nearly 20%, flowering response was not improved by more than 7% in any variety – by any of the vernalisation treatments tried in this series of experiments.
P.T.B. 10		98·9	100·0	96·9	96·4	
Co. 21		97·1	96·6	97·2	97·0	
G.E.B. 24		97·2	96·9	96·8	93·9	
A.K.P. 5		98·3	99·9	98·8	95·4	
A.K.P. 8	80·9	97·8	99·1	98·9	08·4	
M.T.U. 7		101·0	97·9	97·6	98·7	

APPENDIX 1.—*contd.*

Varieties.	Vernalisation Treatments					Remarks.
	D. 22.	D. 14.	D. 7.	L. 7.	L. 14.	
(d) Effect on Grain Yield						
A.D.T. 3		95·5	80·8	80·6	122·1	(1) G.E.B. 24, A.K.B. 8 and A.K.P. 5 are definitely responsive to vernalisation treatments in grain yield, the increase ranging from 12 to 38%.
P.T.B. 10		88·5	101·3	86·2	91·2	
Co. 21		103·8	97·3	110·2	104·5	
G.B.B. 24		130·2	119·8	127·3	133·0	(2) The three short duration varieties A.D.T. 3, P.T.B. 10 and Co. 21 are not so responsive, except A.D.T. 3 under L. 14 treatment.
A.K.P. 5		113·9	119·5	118·5	118·9	
A.K.P. 8	79·0	137·9	124·5	125·6	114·5	
M.T.U. 7		107·5	97·2	99·3	93·6	(3) M.T.U. 7 also does not show any definite improvement in grain yield as a result of vernalisation.
(e) Effect on Straw Yield						
A.D.T. 3		101·4	95·6	104·8	96·3	(1) General trend is similar to grain yield responses though less marked. Here too, G.E.B. 24 and A.K.P. 8 show a consistant increase over controls under different vernalisation treatments.
P.T.B. 10		95·3	113·3	81·3	107·2	
Co. 21		102·9	106·7	111·7	101·1	
G.E.B. 24		107·3	110·9	110·7	108·2	
A.K.P. 5		95·4	92·4	97·3	101·3	(2) In A.K.P. 5, the straw yield tends to be reduced by vernalisation - though the grain yield is increased.
A.K.P. 8		133·7	119·7	116·1	103·3	
M.T.U. 7		94·8	94·2	98·3	90·9	(3) M.T.U. 7 and the short duration types A.D.T. P.T.B. 10 and Co. 21. are not responsive

Note:— D. 22 = Seeds vernalised in total darkness for 22 days;
D. 14 = " " " " " 14 "
D. 7 = " " " " " 7 "
L. 7 = " Vernalised in continuous illumination for 7 days;
L. 14 = " " " " " " 14 "