Floral Induction in Rice Plants

By Hiroshi SUGE

Department of Plant Physiology and Genetics,
National Institute of Agricultural Sciences

Flowering process, as well as other physiological processes of plant, proceeds as an expression of the genetic programs involved in a plant. In the flowering process, however, plants utilize changes of environmental factors originated from the earth revolution and rotation efficiently as a signal.

In the investigation of flowering physiology, stress has been placed upon the analysis of those environmental factors as well as that of chemical entity which links environmental stimulus and actual floral differentiation.

In rice plants, a huge amount of work has been accumulated until now in Japan and other countries on the environmental factors that are influencing heading time but no attempt was undertaken on the physiological or biochemical nature of the flowering process. Subsequently this article introduces such kind of study in a photoperiod sensitive rice variety, Zuiho.

Quantitative evaluation of flowering

Rice plants pass several different anatomical stages in the flowering process from the differentiation of primary rachis-branch primordia to the late stages of reproductive division. Arrangement from the early to the late stages chronologically will show a quantitative presentation of floral development. The criteria for identifying those flower development stages in the apical bud of rice plant are presented in Table 1.

Table 1. Criteria for determining floral stages in the apical bud in rice plant

Floral stage	Criterion	Length of panicle
0	Before differentiation of primary rachis-branch primordia	
1	Differentiating stage of primary rachis-branch primordia	
2	Differentiating stage of secondary rachis-branch primordia	0. 5–0. 9 mm
3	Early stage of flower primordia differentiation	1. 0–3. 0 mm
4	Late stage of flower primordia differentiation	3. 5–15. 0 mm
5	Reproductive cell formation stage	1. 5–5. 0 cm
6	Early stage of reduction division	5–10 cm
7	Late stage of reduction division	10–20 cm

Flower development as expressed in terms of floral stage sequence is illustrated in Fig. 1. Such quantitative evaluation of flowering process is an important first step to analyze the process. Actual application of the criteria shown in Fig. 1 to evaluate flowering process indicated that this floral stage system is useful for the purpose (Fig. 2).

Synthesis and translocation of floral stimulus

How many inductive cycles are necessary to induce flowering? The number of photoperiodic cycles necessary to induce flowering varies depending on the age of plants. Usually,

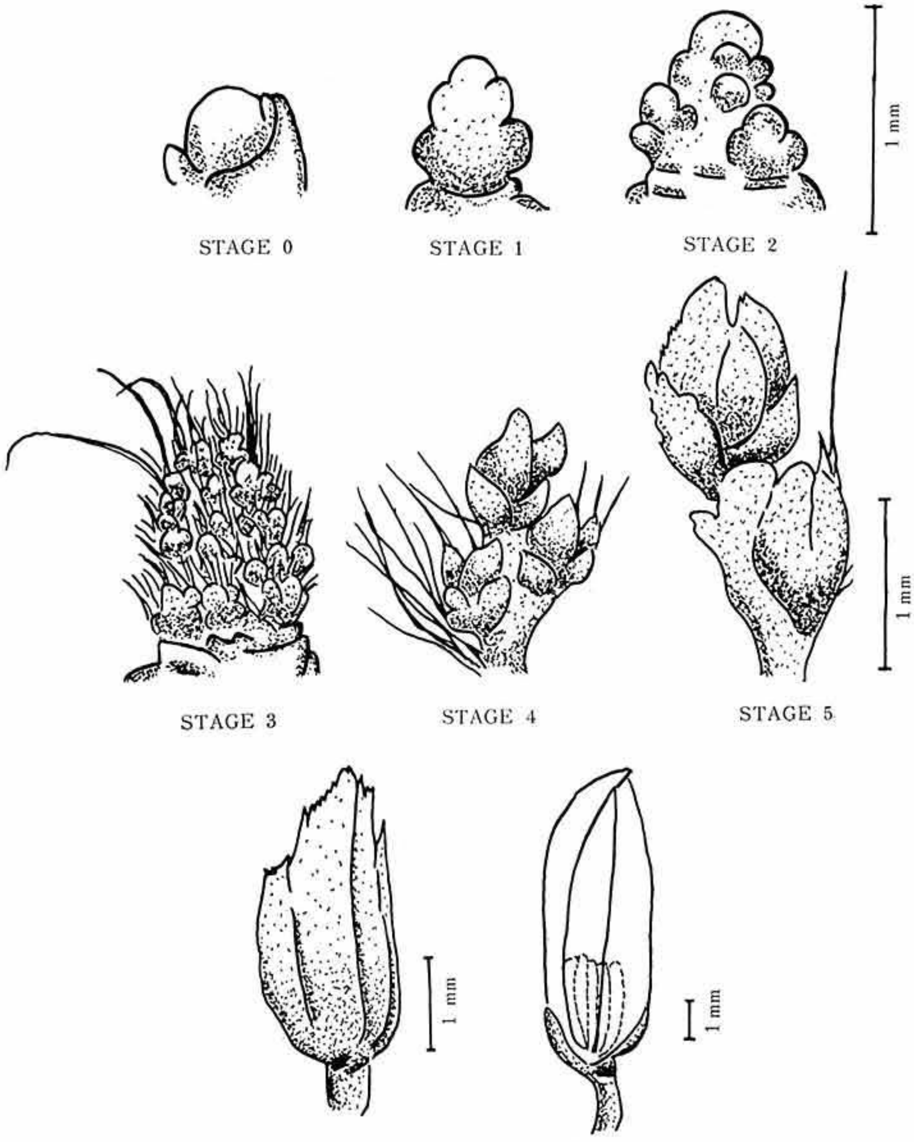

Fig. 1. Developing inflorescence and flower primordium of rice plant illustrating the sequence of floral stage described in Table 1

rice plants require several or more inductive photoperiodic cycles for inducing flowering.

Aged plants, however, can induce flowering even after only a single inductive cycle but even in those cases increasing cycles result in increased flowering responses, indicating that replication of inductive treatments accumulate some entity favorable for floral development (Fig. 3).

Existence of such entity, called "floral stimulus," can usually be demonstrated using defoliation experiments. Application of such techniques in the rice variety demonstrated that "floral stimulus" is produced in the leaves subjected to inductive photoperiods and it is translocated into the apical bud. The amount of floral stimulus produced is almost parallel to the number of inductive cycles given.

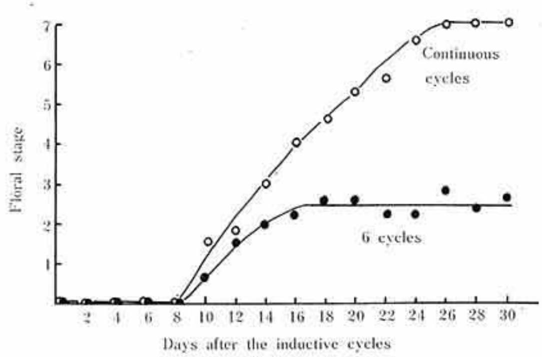

Fig. 2. Floral development curve. Floral development under continuous short day (8 hr light+16 hr dark) and by six inductive cycles

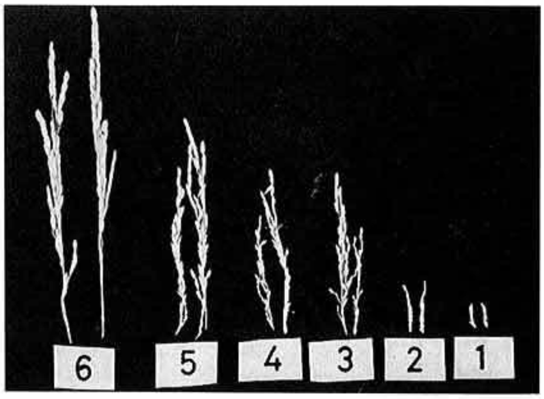

Fig. 3. Floral development due to different number of inductive cycles given at 14 leaf stage

Plants with 7–8 leaves were treated with 15, 10 or 6 cycles, and then shifted to non-inductive photoperiod. Thirty days after the beginning of inductive treatment floral stages were determined. Those experiments show that different amount of floral stimulus was produced by different number of photoperiodic cycles but the rate of translocation of floral stimulus is the same within the three curves (Fig. 4). Translocation of floral stimulus is dependent upon temperature.

Aging effect—attempts of analysis

Dependence of photoperiodic sensitivity of a given variety upon age can be called aging effect. The existence of aging effect in the rice variety is summarized in Fig. 5. The amount of growth inhibitors detected in acidic and neutral fractions of methanol extract reduced greatly accompanying the plant age progress (Fig. 6). It is not certain whether the aging effect essentially depends on the amount of endogenous inhibitors or not, but it can be said that the role of inhibitors in floral induction in the rice plant is one of the important problems in the biochemical aspects of flowering in rice plants.

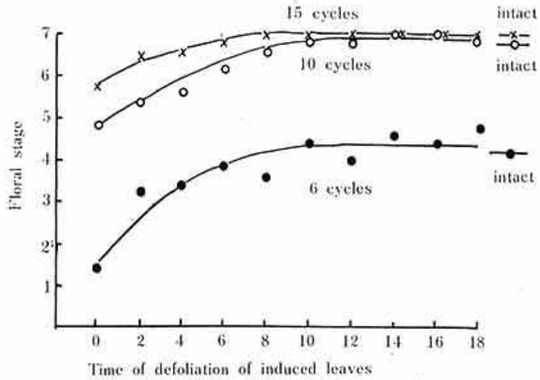

Fig. 4. Translocation of floral stimulus from rice leaves as demonstrated by removal of induced leaves at different times after the end of inductive cycles

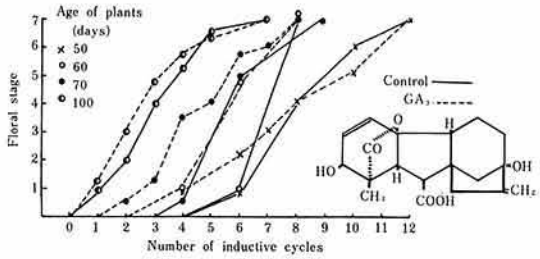

Fig. 5. Effect of GA_3 on the floral development in relation to number of inductive cycles at different plant ages

Gibberellin A_3(GA_3) reduced the minimum numbers of inductive cycles necessary to induce flowering. As shown in Fig. 5, acceleration of reproductive development by GA_3 was evident in the plants to which several inductive cycles were given although GA_3 did not induce flowering under non-

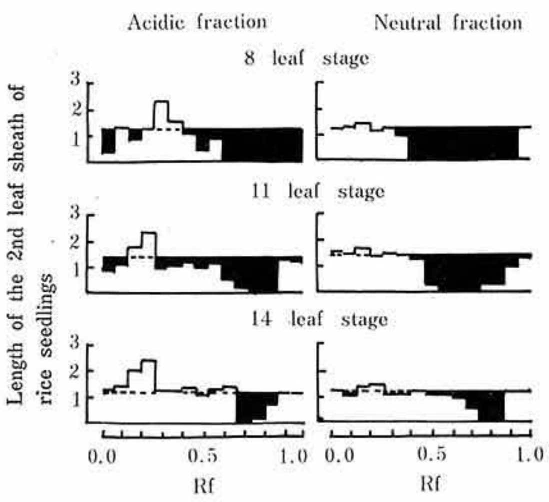

Fig. 6. Histograms showing inhibitory activity of methanol extract at different plant ages

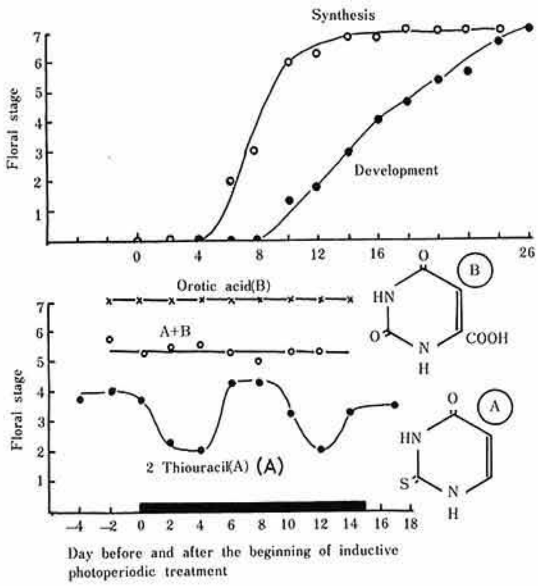

Fig. 7. Effects on flowering of an antimetabolite of nucleic acid, 2-thiouracil, applied at different times in relation to inductive treatment. Upper curves indicate floral stimulus synthesis and floral development

inductive photoperiods. GA may manifest its effect by preventing or masking the inhibitor action that will interfere with production or action of floral stimulus.

Another explanation of making effective GA applied to rice plants is that GA promotes cell division in the shoot apex so that floral stimulus works more effectively since GA promotes the meristimatic activity also in rice plants.

Use of antimetabolites—biochemical approches

If flowering is inhibited by the application of certain antimetabolites which inhibit specific metabolic step in other organisms, it may be considered that the suspected step is implicated in the flowering process. Its participation can be further tested by making an attempt to reverse the effect of the antimetabolites by simultaneous application of a suspected corresponding metabolite.

Antimetabolites of nucleic acid metabolism such as 5-bromouracil, 2-thiouracil and 8-azaguanine, inhibited flowering of the rice variety. These experiments of which one of them is shown in Fig. 7, indicate that 2-thiouracil was effective in two phases of photoperiodic induction, period of floral stimulus synthesis and that of the early stage of floral development. It is still pending that what part of flowering process, including hormone synthesis, translocation of hormone and differentiation or development of flower, is most strongly inhibited by the antimetabolites of nucleic acid. But it is suggested that nucleic acid metabolism plays an important role on hormone synthesis and floral development in apical meristem.

Conclusion

It is premature to consider the flowering process of rice plants as a whole but several attempts of analysis, which are introduced in this article, will postulate the process as a series of several steps; perception of environmental signal, synthesis and translocation of floral stimulus (hormone), flower bud differentiation and floral development. Complete elucidation of the process, however, is a topic of future study.

References

1) Suge, H. & Osada, A.: Physiology of flowering in rice plants. I. Synthesis and translocation of floral stimulus. *Proc. Crop Sci. Soc. Japan*, **36**, 32–36 (1967).

2) Suge, H. & Osada, A.: Physiology of flowering in rice plants. II. Inhibition of photoperiodic floral induction by antimetabolites of nucleic acid. *Proc. Crop Sci. Soc. Japan*, **36**, 37–41 (1967).

3) Suge, H.: Physiology of flowering in rice plants. III. Biochemical aspect on the aging effect of floral induction with special reference to the change of endogenous growth inhibitors. *Proc. Crop Sci. Soc. Japan*, **37**, 156–160 (1968).

4) Suge, H.: Physiology of flowering in rice plants. V. Persistence of applied gibberellin A_3 and A_7 and their effects on the photoperiodic floral induction. *Proc. Crop Sci. Soc. Japan*, **41**, 51–56 (1972).