Modeling Photoperiod Reactions of Rice Plants Under Natural Daylength

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Abstract

The heading dates of photoperiod-sensitive rice plants under natural daylength were investigated in this present study. Six cultivars of rice were sown at two-week intervals over one year period in a greenhouse and maintained under constant temperature. Rice plants sown between August and February were consistent in the number of days required from emergence to heading, while those sown between March and July required more time.

Our model is based on accumulated water temperatures from emergence to heading under short daylength conditions, and can be transformed into the developmental index (DVI). The developmental index is the sum of the developmental rates (DVR) from the emergence day, and is 1 on the heading day. The developmental rate was calculated using non-parametric methods.

Keywords: modeling, rice plants, natural daylength, photoperiod-sensitive, non-parametric methods

1. Introduction

Many studies concerning photoperiod-sensitive rice plants have been conducted under constant daylength. However, since daylength fluctuates over the year, photoperiod-sensitive rice was examined under natural daylength (and constant air temperature) conditions to predict heading time using meteorological data.

2. Methodology

Six rice plant cultivars were sown at two-week intervals over one year period in a greenhouse. Air temperature was maintained at a constant 24 degrees C[elsius] throughout the year, but water temperature decreased during winter (Fig.1). Daylength was calculated using standard equations (Kurata and Okada 1984) as shown in Figure 2.

Fig.1. Daily mean air temperature (—) and water temperature(.....) in controlled green house

3. Results and discussion

3.1 Experimental results

Cultivars sown between August and February were nearly unvarying in the number of days required from emergence to heading. However, cultivars sown between March and July required more time, and results among cultivars were inconsistent (Fig.3).

3.2. Modeling and discussion

From these results, the authors assumed the accumulated water temperature from emergence to heading under short daylength to be the base value. In addition, accumulated water temperature from emergence to heading is larger than that under short daylength by the accumulated functions of daylength. This is represented in the following equation:

$$T_i - S = \sum_{i=a}^h f(L_i) \quad (1)$$

where T_i is water temperature, L_i is daylength in the i -th day, S is accumulated water temperature from emergence to heading under short daylength, a is the day on which rice plants start to sense daylength and h is the heading day.

This model can be transformed into the developmental index (DVI) which Horie and Nakagawa(1990) proposed as emergence day = 0, heading day = 1.

$$DVI_h = \sum_{i=1}^h DVR_i = 1 \quad (2)$$

$$\begin{aligned} DVR_i &= T_i / S & (i \leq a) \\ DVR_i &= (T_i - f(L_i)) / S & (a < i) \end{aligned} \quad (3)$$

where DVI_h and DVR_i are the developmental index on heading day and the developmental rate on the i -th day, respectively.

The $f(L_i)$ and DVR_i were calculated using non-parametric methods which Takezawa and Tamura (1991) developed.

Fig.2. Daylength in the experimented point in 1988

Fig.3. Days from emergence to heading of each cultivar sown in 2 weeks interval

Fig.4. $f(L)$ defined in eqns.(1) was calculated using nonparametric method

We were able to reveal the form of the developmental rate as shown in Figure 5. The developmental rate was constant when it was shorter than the critical daylength. Over this critical value, however, the developmental rate decreased in direct proportion to daylength.

Figure 6 shows the number of days required from emergence to heading calculated in this model. It almost exactly corresponds with observed values (Fig.3).

4. Conclusions

(1) The heading reaction of photoperiod-sensitive rice under natural daylength and constant air temperature was examined. The number of days from emergence to heading was nearly unvarying under conditions of short daylength.

(2) Our model can be transformed into the developmental index, which is the sum of the developmental rates (DVR).

(3) The developmental rate calculated using non-parametric methods was constant when it was shorter than the critical daylength. Over this critical value, however, the developmental rate decreased in proportion to daylength.

(4) The number of days required from emergence to heading calculated in this model corresponded almost exactly with observed values.

Fig.5. DVR defined in eqns.(3),(4)

Fig.6. Calculated days from emergence to heading

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