RESEARCH ON THE PHOTO-TEMPERATURE MODEL FOR THE DEVELOPMENTAL RATE OF RICE

Lan Hongdi (蓝鸿第)

Academy of Meteorological Science, State Meteorological Administration, Beijing

and *Jiang Maoji* (江懋济)

Bureau of Meteorology of Jiangsu, Nanjing

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ABSTRACT

Rice is one kind of crops with short length of light, its developmental rate in the photophase depends on the light-length and temperature. Since uncultivated rice was discovered in China, about 40,000 species of rice, including photo-sensitive and temperature-sensitive types, have been growing. A number of researches have been carried out by agrometeorologists in this field. The purpose of this paper is to develop a photo-temperature model based on a considerable amount of experimental data.

I. DATA

The data used in this paper came from two kinds of experiments: (1) Sowing was carried out on different dates (18 March, 16 May, 12 July) under the condition of the artificially

Table 1 The Species of Rice and Their Photosensitive Types*

Experimental Treatment	Species	Photosensitive Type	No. of Sowing Date
Length of Darkness Varied Artificially	Bantianzi	I	30
	Aizizhan	I	30
	Bolizhan	II	30
	Sanshizi	II	30
	Shuibaitiao	III	30
	Guihuaqiu	III	30
	Huangkezao	IV	30
	Zhechang 9	V	30
	Shuangjiangbai	V	30
	Laolaiqing	V	30
	Xianyouben	VI	30
	Tangpuai	VI	30
Natural Condition	Nante 16	II	38
	Weiguo 7	II	44

* For the photosensitive types see Refs. [1, 2]

varied lengths of daily darkness (12.50, 12.17, 11.83, 11.50, 11.17, 10.83, 10.50, 10.17, 9.83, 9.50 hours) in Guangzhou in 1963, where the length of daily darkness is obtained by the subtraction of light-length (hr) from 24; (2) Sowing was completed under natural condition on different dates with an interval of about 15 days, starting in January and ending in December, in Guangzhou from 1962 to 1964. The species of rice used in the experiments are listed in Table 1.

II. ANALYSIS

1. *Correlations between Developmental Rate and Meteorological Factors*

The photophase of rice is generally defined as the duration required from five leaves to the differentiation of ear[3,4]. The developmental rate (V) in the duration is $V=(1/N)\times 10^4$, where N is the number of days for completing the photophase. The following quantities will be considered in the analysis: for the photosensitive types I and II, they are the daily mean temperature (X_2), the daily mean minimum of temperature (X_3) and the daily mean maximum of temperature (X_4); for the photosensitive types III to VII, one more quantity, mean length of daily darkness (X_1), is calculated besides X_2, X_3, and X_4.

The simple correlaton coefficients r_i between V and X_i for various species are calculated and listed in the order of r value in Table 2.

Table 2 The Simple Correlation Coefficients r_i between V and X_i

Species	A		B		C		D	
Bantianzi I	X_2	0.85	X_4	0.83	X_3	0.83		
Aizizhan I	X_4	0.97	X_2	0.93	X_3	0.92		
Bolizhan II	X_4	0.72	X_3	0.71	X_2	0.00		
Sanshizi II	X_3	0.69	X_2	0.68	X_4	0.66		
Shuibaitiao III	X_1	0.86	X_4	0.60	X_3	0.43	X_2	0.36
Guihuaqiu III	X_1	0.84	X_4	0.65	X_3	0.56	X_2	0.54
Huangkezao IV	X_1	0.82	X_4	0.54	X_3	0.50	X_2	0.49
Zhechang 9 V	X_1	0.95	X_4	0.68	X_2	0.60	X_3	0.58
Shuangjiangbai V	X_1	0.93	X_4	0.64	X_3	0.61	X_2	0.59
Laolaiqing V	X_1	0.91	X_3	0.64	X_2	0.63	X_4	0.57
Xianyouben VI	X_1	0.94	X_4	0.74	X_3	0.63	X_2	0.58
Tangpuai VII	X_1	0.91	X_3	0.67	X_2	0.66	X_4	0.46
Weiguo 7 II	X_4	0.96	X_2	0.96	X_3	0.95		
Nante 16 II	X_4	0.44	X_2	0.41	X_3	0.40		

It can be seen from Table 2 that among 6 species with photosensitive types I and II, there are 4 species having highest correlation coefficients between X_4 and V, one between X_3 and V, and one between X_2 and V; the percentages are 67%, 16% and 16% respectively. For 8 species with photosensitive types III to VII, all highest correlation coefficients are found between X_1 and V, so it gives a 100% percentage, and there are 6 species for which the secondary highest coefficients occur between X_4 and V, but only two between X_3 and V, so the percentages are 75% and 25% respectively.

2. *Establishment of a Model*

It is suggested that the functional relationship between the developmental rate of rice

and meteorological factors

$$V=f(X_1,X_2,X_3,X_4) \quad (1)$$

can be written as a following polynomial[5,6,7]

$$V(X_i)=b_{0i}-b_{1i}X_i+b_{2i}X_i^2. \quad (2)$$

Moreover, a factorial model is used to describe $V(X_i)$,

$$V=V_1(X_1)V_2(X_2)V_3(X_3)V_4(X_4). \quad (3)$$

In order to determine the parameters in Eq. (2), the coefficients of multiple correlation R_i between the developmental rates and meteorological factors for 16 species are first calculated, then the X values are put into the equation in the order of R value. Therefore, the parameters in the photo-temperature model of developmental rate of rice for various species are obtained and given in Table 3.

Table 3 The Parameters of a Photo-Temperature Model for Developmental Rate of Rice

Species	Factor	Parameters			Standard Deviation
		b_0	b_1	b_2	
Bantianzi	X_2	−669.075	53.044	−0.848	7.64
	X_4	2.909	−0.124	0.002	7.78
Aizizhan	X_4	−88.400	3.483	0.117	3.38
	X_2	3.933	−0.222	0.004	3.41
Bolizhan	X_4	7511.380	−487.596	8.031	9.24
	X_3	0.717	0.024	−0.001	9.40
Sanshizi	X_3	2350.599	−200.780	4.580	16.92
	X_2	4.654	−0.285	0.006	17.19
Shuibaitiao	X_1	948.105	−172.085	9.043	16.43
	X_4	−1.514	0.119	−0.001	7.58
Guihuaqiu	X_1	−1476.627	263.091	−10.157	25.64
	X_4	−3.443	0.228	−0.003	10.378
Huangkezao	X_1	−1641.804	289.111	−11.135	31.04
	X_4	−16.318	1.075	−0.017	16.50
Zhechang 9	X_1	105.273	−53.181	5.177	21.06
	X_4	−0.917	0.086	−0.001	15.04
Shuangjiangbai	X_1	560.365	−139.220	9.123	23.48
	X_4	0.752	−0.025	0.001	17.24
Laolaiqing	X_1	−1271.603	194.564	−5.908	28.48
	X_3	−9.253	0.855	−0.018	19.09
Xianyouben	X_1	1632.910	−333.723	17.697	19.96
	X_4	6.579	−0.396	0.007	16.69
Tangpuai	X_1	3202.894	−643.254	32.775	38.13
	X_3	2.369	−0.199	0.006	25.478
Weiguo 7*	X_4	−52.717	3.565	−0.019	3.77
	X_2	1.554	−0.047	0.001	3.90
Nante 16*	X_4	−366.419	27.035	−0.438	14.15
	X_2	4.184	−0.258	0.005	14.50

* Means that the experiments were carried out under natural condition.

It should be noted that the parameters are given for only two sub-models in Table 3, because including other parameters into the model is not able to improve the results.

III. DISCUSSION

Now let us discuss the results:

(1) An empirical formula for the relationship between the developmental rate of crops and the temperature has been suggested by Soviet scientist Leesonko:

$$A+Bn=\Sigma T$$

where A is the effectively accumulated temperature, B the lower limit of temperature in biology, n the number of days during which the daily mean temperature required for completing the development of crops exceed the lower limit of biological temperature. ΣT means the sum of the daily mean temperature. It can be seen from Table 3 that the maximum and minimum of temperature are more important for the developmental rate of rice in its photophase than the daily mean temperature.

(2) The developmental rate of rice depends on the length of daily darkness and temperature according to Table 3. Table 3 indicates that for the species with strongly photosensitive types III to VII, the most important factor which determines the developmental rate of rice is the length of daily darkness, while the maximum and minimum temperature are less important. But for the species with weakly photosensitive types I and II, temperature is only one factor which is used to determine the developmental rate of rice. The results obtained from calculation show that the relationship between the developmental rate and the meteorological factors is adequately described by a factorial model.

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