HYBRID RICE BREEDING

I. Variations of flowering time and duration[1]

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Abstract

The flowering time and duration of rice varieties were investigated. Four environmental factors were artificially chosen to measure their effect on the flowering characters. Flowering characters are greatly influenced by the environmental changes particularly by average temperature and light intensity variation. Further, it is possible to modify and standarize the data about flowering time obtained on different days with the coefficient of partial regression.

Introduction

The hybrid varieties have been produced in many outcrossing crops such as maize, sugar beet and onion. It is, however, more difficult for selfing crop to obtain the hybrid varieties, mainly due to the low productivity of F_1 seeds.

Recent success in hybrid sorghum breeding and the advancement of similar work in wheat have encouraged the rice breeders to give a great attention in this area.

In order to carry out the hybrid breeding, male sterile cytoplasm and fertility restoration gene have to be made available. In addition, the parents with high F_1 heterosis and high F_1 seed productivity have to be found. Male sterile cytoplasms have been found in wild (Katsuo and Mizushima 1958) as well as cultivated rices (Shinjyo 1969). The gametophytic fertility restoration genes were discovered by Shinjyo in 1969. Parents with heterosis have recently been discovered in our laboratory (unpublished data)

The flowering time of rice is variable according to environmental changes, whereas the daily flowering duration is about one to three hours according to Katayama (1970). However what and how the environmental conditions

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affect the two phenomena is not known. This paper reports our investigations on the temperature and light intensity effects on the rice flowering characters.

Materials and Methods

Two *japonica* varieties, Taichung 65 (T. 65) and Tainan 5 (TN 5), as well as two *indica* varieties, Taichung Native 1 (TN 1) and Taichung Hsien 2 (TH 2) were used in this study. The rices were transplanted in the concrete beds at the Institute on August 15 1969. The flowering time and duration were investigated daily between Oct. 11–31 for 14 days. No observation was made on rainy and extreme cold days.

The time when more than five spikelets in a panicle opened their lemma and palea was taken as flowering time (FT). The interval between opening and closeing of the flowering spikelets was recorded as flowering duration (FD). For each variety, four plants were chosen for investigation each day.

Temperature (C°) and light intensity (lux) immediately above the plant were recorded from A.M. 8.00 to the flowering time of a given plant at thirty miunites intervals. Four environmental factors were artificially chosen to measure their effect on the flowering characters in this study. They are defined as follows: 1) Average temperature (AT) was taken from A.M. 8.00 to the flowering time of each plant. 2) Temperature variation (TV) was defined as the total temperature changes took place in the hour immediatly preceeding the flowering time of each plant. 3) Average light intensity (AL) was taken from A.M. 8.00 to the flowering time of each plant. 4) Light intensity variation (LV) was defined as the total light intensity changes took place in the hour immediatly preceeding the flowering time of each plant.

Results

I. *Variance analysis*

As shown in Table 1, the flowering time (FT) of *japonica* varieties are slightly later than that of *indica* varieties. There are no difference in the flowering durations (FD) between the two groups, though the *japonica* varieties exhibited larger deviation. In Table 1, the environmental factors for each variety vary within the same day. It is because the data were taken based on the flowering times which differ with one another among rice varieties.

In order to understand the variation components of flowering characters variance analysis was performed. As shown in Table 2a, the variance of flowering time (FT) from environment as well as from the interaction between environment and variety were highly significant, while that of from variety

Table 1. *Average and deviation of flowering characters and environmental conditions.*

	Taichung 65	Tainan 5	Taichung Native 1	Taichung Hsien 2	Average of 4 Var.
Flowering* time (min)	64.84±36.56**	64.31±41.10	57.79±34.48	57.24±33.73	61.03±35.80
Flowering duration (min)	77.16± 8.87	78.42± 8.75	76.01± 5.66	75.57± 4.26	76.78± 6.19
Average temperature (C°)	23.44± 1.48	23.45± 1.37	23.35± 1.51	23.36± 1.51	23.41± 1.46
Temperature variation (C°)	2.25± 0.91	2.21± 1.28	2.18± 1.03	2.11± 1.10	2.21± 1.04
Average light intensity (×100 lux)	57.26±13.86	57.41±13.21	58.09±15.30	57.24±13.80	57.51±13.86
Light intensity variation (×100 lux)	37.14±31.97	41.36±28.56	38.28±33.48	37.29±31.32	38.52±30.40

* A. M. 9.00=0

** $m \pm \sigma$

Table 2a. *Variance analysis of flowering time.*

	S. S.	df.	F.	P.	Variance-component	% of S. S.
Days	266,541.97	13	323.80	0.001	$\sigma_E^2+16\sigma_D^2$	91.35
Varieties	2,802.23	3	3.09	0.05	$\sigma_E^2+ 4\sigma_{V\times D}^2+60\sigma_V^2$	0.96
Day × Var.	11,782.14	39	4.77	0.001	$\sigma_E^2+ 4\sigma_{V\times D}^2$	4.04
Error	10,637.50	168			σ_E^2	3.65
Total	291,763.84	223				100.00

Table 2b. *Variance analysis of flowering duration.*

	S. S.	df.	F.	P.	Variance component	% of S. S.
Days	7,973.77	13	28.48	0.001	$\sigma_E^2+16\sigma_D^2$	54.70
Varieties	275.34	3	1.32	N. S.	$\sigma_E^2+ 4\sigma_{V\times D}^2+60\sigma_V^2$	1.89
Day × Var.	2,710.60	39	3.23	0.001	$\sigma_E^2+ 4\sigma_{V\times D}^2$	18.59
Error	3,618.75	168			σ_E^2	24.82
Total	14,578.46	223				100.00

was only significant at 5% level. Comparison of sums of square indicates that 91% of the variance was due to environments, while only less than 5% was contributed by the variety and their interactions. Concerning the flowering duration (FD), the variance from environment as well as the interaction between environment and variety were highly significant but that from variety was no significant (Table 2b). Comparism of the components of sums of square between flowering time and duration indicates that the environments contribute more variance to the flowering time (FT) than flowering duration (FD).

II. *Correlation analysis*

Correlation analysis was made for the flowering characters and environmental factors in order to elucidate their actural relationships. As shown in Fig. 1. flowering time (FT) and duration (FD) are significantly correlated in any varieties. Further average temperature (AT) and light intensity variation (LV) are negatively correlated with flowering time and duration (Table 3). It is concluded that higher temperature and larger light intensity variation stimulate the opening of flowers and extend the flowering duration. Average light intensity has no effect on either flowering time or duration. The data (Table 3) also indicateds that temperature variation affects the flowering duration but not the flowering time.

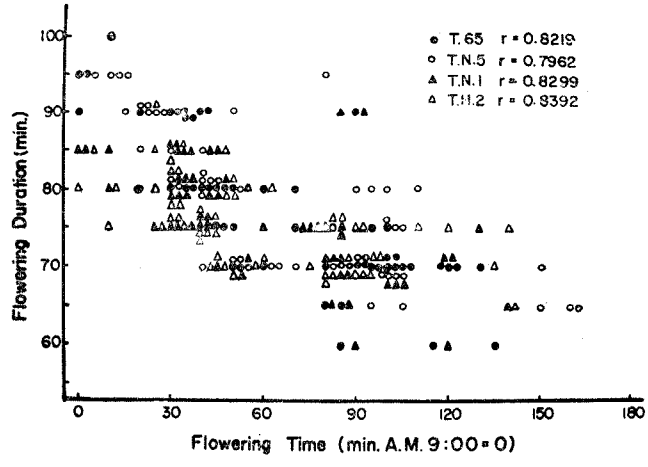

Fig. 1: Correlation relationship between flowering time and duration.

Table 3. *Correlation relationship among flowering characters and environmental conditions.*

	Flowering duration	Average temperature	Temperature variation	Average light intensity	Light intensity variation
Flowering time	−0.863**	−0.714**	0.294	0.286	−0.644**
Flowering duration		0.569*	0.548	−0.280	0.593*
Average temperature			−0.630*	−0.394	0.417
Temperature variation				0.031	0.076
Average light intensity					−0.756**

** 1% level
* 5% level

Average temperature (AT) and light intensity (AL) are negatively correlated respectively with temperature (TV) and light intensity variations

(LV). For this reason, the variations are considered due mainly to the decreased temperature and light intensity.

III. *Regression analysis*

Regression analysis were made to assess the extent to which the flowering characters are affected by the environmental factors. In addition, based on the coefficient of regression, flowering characters recorded in different environments can be modified toward those expected in a hypothetical standard environment. Simple regression coefficient among flowering characters and environmental factors are shown in Table 4.

Table 4. *Simple regression relationship among flowering characters and environmental conditions.*

Independent variable Function	Flowering duration (FD)	Average temperature (AT)	Temperature variation (TV)	Average light intensity (AL)	Light intensity variation (LV)
FT (min)	−4.998**	−17.516**	7.00	0.738	0.759*
FD (min)		2.412*	3.247*	−0.125	0.121*
AT (C°)			−0.879*	−0.042	0.020
TV (C°)				0.002	0.003
AL (×100 lux)					−0.345*
LV (×100 lux)					

** 1% level
* 5% level

Simple regression analysis, however, can not avoid the error incurred by the correlations among the environmental factors. For this reason, the partial regression coefficients were also presented in Table 5. It was found that the flowering time (FT) was significantly regressed to the average temperature (AT), light intensity (AL) as well as light intensity variation (LV). Partial regression represented 89% of the total variance. This means that the four environmental parameters artificially chosen in this study account for most of the environmental elements affecting the flowering time (FT).

Table 5. *Partial regression relationship between flowering time and environmental conditions.*

	Coefficient of partial regression	*t* value	*p*
^{b}AT-FT (min)	−18.3703	−4.2302	0.01
^{b}VT-FT (min)	6.6347	1.1999	N.S.
^{b}AL-FT (min)	− 1.4659	−3.3499	0.01
^{b}VL-FT (min)	− 0.8785	−4.0096	0.01

In Table 6, the flowering times (FT) were modified respectively by the simple and partial regression coefficients. Standard diviations of the flowering times (FT) modified by partial regression coefficients are smaller than those of the original ones for any of the varieties used. No such effect could be detected for simple regression coefficients.

Table 6. *The flowering times after modified by the coefficients of simple and partial regression.*

	Taichung 65	Tainan 5	Taichung Native 1	Taichung Hsien 2	Average of 4 Var.
Original flowering time (min)	64.84±36.56*	64.31±41.10	57.79±34.43	57.24±33.73	61.03±35.80
Flowering time after modified by coefficient of simple Reg. (min)	64.25±35.43	67.21±32.65	56.13±38.60	56.30±35.61	60.78±34.84
Flowering time after modified by coefficient of partial Reg. (min)	63.46±22.80	67.35±19.42	57.34±25.97	55.46±22.30	62.57±24.44

* $m \pm \sigma$

Discussion

Rice is considered to be a selfing crop. The dehiscence of anther occurs either just before or at the time of spikelet opening resulting in self pollination. The natural outcrossing rate in cultivated rice have been reported by a few workers using different genic makers. Brown (1954) and Butany (1957) reported that the outcrossing rate differs with varieties ranging from 0.52 to 2.49% and 0 to 6.8% respectively. Hak and Ahmed (1965) reported that the outcrossing rate differs not only with varieties but also with localities. Applying mixed culture to avoid the wind effect, Roberts *et al* (1961) reported that the outcrossing rate differed with environmental conditions ranging from 0.04 to 1.07%. Some of the wild rice species *Oryza perennis subsp barthii*, are considered as semi-selfing plants because of the partial self-imcompatibility (Chu *et al* 1970). Worked with *Oryza perennis*, Sakai and Narise (1959) reported that the outcrossing rate ranged from 16.5 to 33.9%. Singh and Saini (1961) also reported that the outcrossing rate of *Oryza perennis* was 2.94%. Outcrossing rates in cultivated rice, therefore, is generally very low.

High outcrossing rate is essential for hybrid rice breeding. To satisfy this requirment, the following manipulations can made; 1) adjustment of the heading date and flowering time of the parents, 2) breeding of varieties with long flowering duration, 3) breeding of varieties with a large number of pollens and 4) elongation of the interval between primary and last heading panicles in a plant,

In this report, we attempted to clarify the variation patterns of flowering time and duration of cultivated rice. Based on such informetion, the aforementioned manipulations 1) and 2) can be made.

Butany and Gangadharan (1960), worked with wild as well as cultivated rices, reported that the flowering time varied from 5.00 AM to 2.30 PM. according to species. The flowering durations also ranged from 1 to 3 hours, according to the same authors. Katayama (1964, 1970) also reported that flowering time vary greatly among rice species and the variations coincide very well with taxonomical relationship. He also demonstrated that the flowering time was greatly influenced by the environmental conditions. Based on his series of studies, katayama (1970) concluded that rices can be grouped into four with respect to their flowering time responses to climatic conditions; 1), those very stable regardless of the climatic changes, 2), those very sensitive to climatic changes 3), those vary mainly with the time of sunrise and, 4), those gradually accelated by the drop in temperature. In addition, Narise (1958) reported that wild rice species showed a marked delay in flowering time on raing or cloudy days whereas the cultivated varieties were affected only to a lesser degree by the weather changes.

In this study, however, we have found that most of the varialility of flowering time was contributed jointly by the environmental factors as well as the interaction between environment and variety. This discrepency, though we have no data for the wild rice, may be due to the difference in experimental materials and localities.

We have demonstrated that it is possible to modify and stardardize the data about flowering time obtained on different days with the coefficient of partial regression. This should be a very useful tool in the breeding of hybrid rice. For instance, if many varieties or segregants are to be investigated, it is frequently necessary to record the flowering times in many days due either to the difference in heading date or laber limitation. With the coefficient of partial regression, however, these data can be standardized thus minimize the errors from daily climatic changes.

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