Photoperiodism in the Genus *Oryza*. III.

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Several factors have been accounted for different photoperiodic sensitivities of rice found among various strains. As reported first by YOSHII (8), a relative difference in sensitivity exists among the strains previously classified as sensitive. Several factors have been accounted for such a difference, among which the aging effect, critical day-length were already considered (4, 5). The determination of differences in photoperiodic sensitivity is to be now considered from a third viewpoint, namely, differential acceleration of heading by an effective short-day-treatments. As a means of expressing acceleration-rate of heading, HARA (2) proposed to use the term "sensitivity coefficient". In the previous paper of the present author (5), three different methods of expressing the acceleration rate were critically compared on the basis of the data obtained by using a few strains.

However, in the previous paper, several problems were remained unclarified, for instance, whether these calculation-methods are used as universal validity for more number of strains or not, whether the data obtained by the indices are stable in every year or unstable, and others. Then, in the present paper, several experiments using many strains belonging to *Oryza* species were done during several years for the sake of solving these problems.

Materials and Method

One hundred and sixty three strains belonging to 9 species of the genus *Oryza*, including 2 cultivated and 7 wild species, were used in the present investigation. Enumeration of the species used, their distribution, chromosome number, genome constitution and the number of strains used are given in Table 1. Experiments reported in the present paper were made four years during 1962 to 1966. As the materials and sowing time are to be described in detail in each experiment, only general method will be given here. The relation of sowing date to growing period (number of days from sowing to heading) was investigated and described in average value of whole plants used.

Seeds of wild species were all husked in order to get uniform germination and were sterilized with 0.1 % Uspulun solution, hydroxymercurichlorophenol, for 4 to 6 hours. Then, they were washed twice with sterilized water and incubated at 30° C in Petri-dishes on filter paper. Two or three days after germination, young seedlings were planted

Table 1. Enumeration of *Oryza* species used in the present studies, their distribution, chromosome number, genome constitution and number of strains used.

Species	Distribution	Chromosome number (2n)	Genome constitution	No. of strains used
O. sativa L.	Asia, Europe, Africa America, Australia	24	AA	40
O. glaberrima STEUD.	Africa	24	AA	2
O. sativa var. *spontanea* ROSCHEV.	Asia	24	AA	46
O. perennis MOENCH	Asia, America	24	AA	40
O. barthii CHEV. et ROEHR.	Africa	24	AA	3
O. stapfii ROSCHEV.	Africa	24	AA	3
O. breviligulata CHEV. et ROEHR.	Africa	24	AA	15
O. officinalis WALL.	Asia	24	CC	13
O. latifolia DESV.	America	48	CCDD	1

Table 2. Average temperature in greenhouse from April 21 till December 7.

Date		Average maximum temperature	Average temperature	Average minimum temperature
		C	C	C
April	21	25.3	21.7	20.7
May	1	24.5	21.3	20.4
	11	22.0	20.1	18.0
	21	21.9	17.5	14.8
	31	23.4	18.7	14.2
June	10	25.1	20.4	16.1
	20	25.9	21.7	17.6
	30	27.0	23.1	20.1
July	10	28.5	24.7	21.6
	20	29.4	25.3	22.1
	30	30.3	25.8	22.5
August	9	30.5	26.1	22.6
	19	30.0	25.4	21.5
	29	29.7	25.3	21.8
September	8	29.1	24.3	20.2
	18	26.9	22.0	18.4
	28	24.6	20.0	16.0
October	8	25.4	21.5	18.4
	18	25.2	22.8	17.4
	28	26.8	21.6	17.5
November	7	24.2	21.9	17.2
	17	25.1	20.9	18.6
	27	24.8	22.3	17.9
December	7	25.1	21.7	16.6

in wooden boxes and kept in upland-condition. Thirty to 40 days after germination, the seedlings were transplanted in pot (30 cm in diameter) filled with garden soil. Three plants were grown in each pot, and under natural day-length, in greenhouse. Heading-date was referred to the time, when the tip of the first ear in a plant was emerging from the leaf-sheath of flag leaf.

Flower-bud-formation occurs about thirty days before the heading, if plants are kept under suitable temperature-condition during their growth-period. Actual temperature of the greenhouse is shown in Table 2. In late spring and the fall, suitable temperature of greenhouse was maintained by the artificial heating system. Astronomical day-length, day-length including the time of civil twilight in the morning and evening, and civil twilight are shown in Table 3. During the experiment, attention was paid for keeping suitable conditions for healthy growth of plant of different species.

Three different methods were used and compared each other for expressing the acceleration-rate of heading; *i.e.*, linear regression of the growing-period on sowing

Table 3. Astronomical day-length, day-length including the time of civil twilight in the morning and the evening, and civil twilight from April 21 till December 7.

Date		Civil twilight (A)	Astronomical day-length (B)	(A)×2 +(B)
		m	h m	h m
April	21	27	13 16	14 10
May	1	28	13 35	14 31
	11	29	13 53	14 51
	21	29	14 9	15 7
	31	29	14 21	15 19
June	10	30	14 29	15 29
	20	30	14 31	15 31
	30	30	14 30	15 30
July	10	29	14 24	15 22
	20	29	14 12	15 10
	30	29	13 58	14 56
August	9	28	13 42	14 38
	19	27	13 23	14 17
	29	26	13 2	13 54
September	8	26	12 41	13 33
	18	26	12 20	13 12
	28	26	11 58	12 50
October	8	26	11 37	12 29
	18	26	11 15	12 7
	28	27	10 55	11 49
November	7	28	10 35	11 31
	17	28	10 18	11 14
	27	28	10 5	11 1
December	7	28	9 55	10 51

time, a linear regression of growing period on day-length and a regression-coefficients of growing period on day-length converted to the angle. Their detailed methods were quite the same to the previous report (5).

Experimental Results

1. *Experiment in 1962*

Twenty six strains belonging to 4 different cultivated- and wild-species were picked up from Indian Continent and used in this experiment ; *i. e.*, 1 strain of *O. sativa*, 14 strains of *O. sativa* var. *spontanea*, 10 strains of *O. perennis* and 1 strain of *O. officinalis*. They are listed in Table 4.

Table 4. Enumeration of *Oryza* species used in 1962, number of strains and their orinigal localities.

Species	No. of strains used	Locality
O. sativa L.	1	Formosa
O. sativa var. *spontanea* ROSCHEV.	14	India
O. perennis MOENCH	1	Burma
〃	9	India
O. officinalis WALL.	1	India

Sowing was made repeatedly 4 times from late spring until summer with 30-days-intervals. Some relationships between sowing time and growing period and acceleration rate are shown in Table 5. In this table, the abbreviations used mean the followings ;

Sowing time, heading date : for instance, 4-17-April 17.

DGP : Difference in growing period between plants sown on April 17 and June 16, estimated from linear regression of growing period on sowing time.

LRC-1 : Coefficient of linear regression of growing period on sowing time.

DDL : Difference between day-length at the time of flower-bud-formation in plants sown on April 17 and June 16.

LRC-2 : Coefficient of linear regression of growing period on day-length at the time of flower-bud-formation.

Angle (°) : Regression-coefficient of growing period on day-length converted to the angle.

S and I : Photoperiodically sensitive and insensitive strains, respectively.

Heading dates were observed during September 25 to October 26 (31-day-duration) when the seeds were sown on April 17, during October 1 to October 26 (25-day-duration) when the seeds were sown on May 17, during October 7 to October 29 (22-day-duration) when the seeds were sown on June 16, during October 10 to November 1 (22-

Table 5. Acceleration-rates of heading of 26 strains observed by delaying their sowing-time (1962).

Strain	Heading date when sown on				Growing period when sown on				DGP and LRC-1		DDL	LRC-2	Angle (°)	Sensi-tivity
	4-17*	5-17	6-16	7-16	4-17	5-17	6-16	7-16						
W0157	10-20	10-24	10-29	-	186	160	135	-	51	0.85	20^{m}	2.55	68.6	S
W0635	10-22	10-24	10-26	10-29	188	160	132	105	56	0.93	9	6.22	80.9	S
W1079	10-25	10-26	10-26	-	191	162	132	-	59	0.98	3	19.89	87.1	S
W1081	10-24	10-26	10-26	10-28	190	162	132	104	58	0.97	5	11.60	85.1	S
W1082	10-26	10-26	10-26	-	192	162	132	-	60	1.00	0	∞	90.0	S
W1083	10-24	10-26	10-26	-	190	162	132	-	58	0.97	5	11.60	85.1	S
W1084	10-26	10-26	10-26	-	192	162	132	-	60	1.00	0	∞	90.0	S
W1085	10-26	10-26	10-26	-	192	162	132	-	60	1.00	0	∞	90.0	S
W1090	10-16	10-16	10-17	-	182	152	123	-	59	0.98	3	19.89	87.1	S
W1091	10-15	10-15	10-17	10-20	181	151	123	96	58	0.97	5	11.60	85.1	S
W1092	10-16	10-16	10-17	10-19	182	151	123	95	59	0.98	3	19.89	87.1	S
W1095	10-25	10-25	10-25	-	191	161	131	-	60	1.00	0	∞	90.0	S
W1098	10-21	10-25	10-26	11- 1	187	161	132	108	55	0.92	12	4.58	77.7	S
W1099	10-22	10-24	10-24	-	188	160	130	-	58	0.97	4	14.50	86.1	S
W1100	10-19	10-20	10-25	10-27	185	156	131	103	54	0.90	13	4.15	76.5	S
W1102	10-24	10-24	10-25	-	190	160	131	-	59	0.98	2	29.50	88.1	S
W1104	10-24	10-25	10-24	10-25	190	161	130	101	60	1.00	0	∞	90.0	S
W1105	10-24	10-23	10-26	10-28	190	159	132	104	58	0.97	5	11.60	85.1	S
W1107	10-19	10-20	10-22	10-21	185	156	128	97	57	0.95	7	8.14	83.0	S
W1108	10-19	10-20	10-22	10-26	185	156	128	102	57	0.95	7	8.14	83.0	S
W1115	10-21	10-22	10-23	10-19	187	158	129	95	58	0.97	4	14.50	86.1	S
W1116	10-21	10-22	10-22	10-25	187	158	128	101	59	0.98	2	29.50	88.1	S
W1117	10-20	10-25	10-21	10-27	186	161	127	103	59	0.98	2	29.50	88.1	S
W1121	10-22	10-22	10-22	-	188	158	128	-	60	1.00	0	∞	90.0	S
W1134	10-10	10- 8	10-11	-	176	144	117	-	59	0.98	2	29.50	88.1	S
124	9-25	10- 1	10- 7	10-10	161	137	113	86	48	0.80	25	1.92	62.5	S

* 4-17: April 17. Explanations in text.

day-duration) when the seeds were sown on July 16, respectively. The growing periods were observed between 161 and 192 days when the seeds were sown on April 17, 137 and 162 days when the seeds were sown on May 17, 113 and 135 days when the seeds were sown on June 16, 86 and 108 days when the seeds were sown on July 16, respectively.

Differences in growing period between plants sown on April 17 and June 16 ranged from 48 to 60 days. The term of forty eight days means that the plants sown on June 16 had headed 12 days, delayed in sowing by 60 days, later than the plant sown on April 17. That of sixty days means that the plants sown on April 17 and June 16 had headed in the same day, nevertheless the latter was sown 60 days more delayed than the former.

Regression-coefficients of the equations (LRC-1) may be used as one of the indices of the acceleration-rate of heading. They varied within the limits of 0.80 and 1.00. Differences between day-length at the time of flower-bud-formation in plants sown on April 17 and June 16, ranged between 0 and 25 minutes. The regression-coefficients of the equations (LRC-2) indicate another index of the acceleration-rate of the heading. They varied within the limits of 1.92 and of infinite quality. These coefficients were converted to angles of the slopes and may be used as the third index of the acceleration-rate of the heading (Angle). They varied within 62.5°, and 90.0°, *i. e.*, 2 strains were shown within 60° and 69°, 2 strains were shown within 70° and 79°, 16 strains were shown within 80° and 89°, 6 strains were shown within 90°, respectively. The strains showing infinite quality in LRC-2 index, showed 90° in Angle index.

Correspondence between three different indices of the acceleration-rate is very good. All the three indices may be used as the measure expressing the acceleration-rate of the heading. LRC-1 indicates acceleration-rate of heading (in number of days) brought forth by delaying the sowing by one day, while LRC-2 and the angle converted from it correspond to acceleration-rate of heading obtained by shortening the day-length by one minute. LRC-2 and its angle may be said to be biologically more significant than LRC-1, as the means of expressing the acceleration-rate of heading. No definite relationship was found between the species and the acceleration-rate of their heading. All of the strains used showed high acceleration-rate.

2. *Experiment in 1963*

The writer was sent to Borneo and Java in March of 1963 for the collection of cultivated and wild rice (3). Fifty two strains belonging to 5 different cultivated and wild species were mainly selected from this collection and used in this experiment; *i. e.*, 37 strains of *O. sativa*, 1 strain of *O. glaberrima*, 1 strain of *O. sativa* var. *spontanea*, 1 strain of *O. perennis* and 12 strains of *O. officinalis*. They are listed in Table 6.

Sowing was made twice, *i. e.*, on June 17 and July 17 with 30-days-interval. Some relationships between growing-period and sowing-time and acceleration-rate are shown

Table 6. Enumeration of *Oryza* species used in 1963, number of strains and their original localities.

Species	No. of strains used	Locality
O. sativa L.	1	Japan
〃	13	North Borneo
〃	20	Brunei
〃	3	Sarawak
O. glaberrima STEUD.	1	Africa
O. sativa var. *spontanea* ROSCHEV.	1	New Guinea
O. perennis MOENCH	1	India
O. officinalis WALL.	1	North Borneo
〃	6	Brunei
〃	4	Sarawak
〃	1	Kalimantan

Table 7. Acceleration-rates of heading of 52 strains observed by delaying their sowing-time (1963).

Strain	Heading date when sown on		Growing period when sown on		Standard deviation at 5% level	DGP	LRC-1	DDL	LRC-2	Angle (°)	Sensitivity
	6-17	7-17	6-17	7-17							
W1263	11-16	12-10	152.3	146.0	0.93	6.3	0.21	45	0.14	8.0	I
W1269	11-16	11-22	152.3	128.0	2.45	24.3	0.82	7	3.53	74.2	S
W1270	11-22	12-11	158.3	147.0	0.93	11.3	0.38	37	0.31	17.2	I
W1272	11-22	12- 5	157.7	141.0	1.85	16.7	0.56	28	0.59	30.5	S
W1273	11-17	12- 3	152.7	139.3	4.88	13.3	0.45	31	0.43	23.3	S
W1274	11-14	12- 4	149.7	140.3	3.16	9.3	0.31	40	0.24	13.5	I
W1275	11-14	11-23	149.7	129.3	5.22	20.3	0.68	18	1.13	48.5	S
W1278	11-23	11-26	159.0	132.3	7.17	26.7	0.89	5	5.34	79.4	S
W1280	11-16	11-19	152.0	125.3	2.79	26.7	0.89	6	4.45	77.3	S
W1281	11-10	11-18	146.0	124.3	4.03	21.7	0.72	14	1.56	57.3	S
W1282	11-11	11-16	146.7	121.7	3.81	25.0	0.83	14	1.64	58.6	S
W1291	11- 8	11-19	143.7	125.0	1.85	18.7	0.62	22	0.85	40.4	S
C8451	11- 7	11-11	142.7	117.3	3.81	25.3	0.85	24	1.06	46.7	S
C8455	11-10	11-16	146.0	122.3	0.93	23.7	0.79	12	1.98	63.2	S
C8460	11-11	11-16	147.3	121.7	2.62	25.7	0.86	10	2.57	68.7	S
C8461	11- 9	11-15	145.3	121.3	2.62	24.0	0.80	16	1.50	56.3	S
C8462	10- 9	11-10	114.0	115.7	2.45	-1.7	-0.60	62	0.00	0.0	I
C8463	10-11	11- 9	115.7	115.3	1.31	0.3	0.01	63	0.01	0.6	I
C8464	10-18	11-18	123.7	124.3	2.07	-0.7	-0.02	65	0.00	0.0	I
C8465	10-18	11-18	123.0	123.7	0.93	-0.7	-0.02	67	0.00	0.0	I
C8466	10-15	11-12	120.0	118.0	5.55	2.0	0.07	61	0.03	1.7	I
C8467	10-14	11-12	119.0	118.3	5.15	0.7	0.02	63	0.01	0.6	I
C8468	10-14	11-12	118.7	118.0	3.46	0.7	0.02	65	0.01	0.6	I
C8470	10-15	11-10	119.7	116.0	0.93	3.7	0.12	56	0.06	3.4	I
C8471	10-16	11-16	121.3	121.7	2.07	-0.3	-0.01	78	0.01	0.6	I
C8475	10-14	11-13	119.0	118.7	2.07	0.3	0.01	65	0.01	0.6	I
C8476	10-18	11-18	123.0	124.0	4.81	-1.0	-0.03	67	0.00	0.0	I
C8477	10- 7	11- 7	112.0	113.3	2.45	-1.3	-0.04	65	0.00	0.0	I
C8479	10- 8	11- 2	113.0	108.3	2.45	4.7	0.16	55	0.08	4.6	I
C8480	10-12	11-12	117.0	118.0	2.07	-1.0	-0.03	64	0.00	0.0	I
C8481	10-12	11-10	117.0	116.0	2.78	1.0	0.03	62	0.02	1.1	I
C8484	10-11	11-11	116.0	116.7	0.93	-0.7	-0.02	67	0.00	0.0	I
C8485	10- 9	11-11	113.7	107.0	2.93	6.7	0.22	51	0.13	7.4	I
C8491	10-14	11-12	119.0	119.0	6.00	0.0	0.00	65	0.00	0.0	I
C8492	10-10	11- 4	115.3	110.0	3.81	5.3	0.18	81	0.07	4.0	I
C8495	10-15	11-14	120.3	120.0	2.45	0.3	0.01	65	0.01	0.6	I
C8498	10- 9	11-16	113.7	115.7	2.31	-2.0	-0.07	81	0.00	0.0	I
C8500	10-12	11-13	116.7	119.0	3.07	-2.3	-0.08	69	0.00	0.0	I
C8502	10- 8	11- 1	113.3	106.7	1.31	6.7	0.21	80	0.08	4.6	I
C8503	10- 8	11- 3	113.0	109.3	3.86	3.7	0.12	57	0.06	3.4	I
C8505	10- 9	11-10	114.0	116.0	4.21	-2.0	-0.07	69	0.00	0.0	I
C8507	10- 4	11- 2	108.3	108.0	5.22	0.3	0.01	65	0.01	0.6	I
C8508	10-11	11- 7	115.7	113.3	5.47	2.3	0.09	70	0.04	2.3	I
C8510	11- 5	11-14	140.7	120.0	4.34	20.7	0.69	19	1.09	47.5	S
C8511	11- 5	11-16	141.3	122.0	0.93	19.3	0.64	14	1.38	54.1	S
C8512	11- 7	11-16	142.7	122.0	1.85	20.7	0.69	20	1.04	46.1	S
C8515	11- 7	11-17	143.3	122.7	1.31	20.7	0.69	22	0.94	43.2	S
C8516	11- 4	11-16	140.0	122.0	2.78	18.0	0.60	26	0.69	34.6	S
KA	9-16	10- 2	90.7	77.0	3.93	13.7	0.46	35	0.39	21.3	S
C7695	10-29	10-30	133.7	105.0	2.45	28.7	0.96	4	7.18	82.1	S
W0120	10-23	10-31	127.7	106.0	3.23	21.7	0.72	17	1.25	51.3	S
W1235	11- 1	11-10	137.3	116.3	5.71	21.0	0.70	19	1.11	48.0	S

in Table 7. In this table, the abbreviations used mean the followings ;

DGP : Difference in growing-period between plants sown on June 17 and July 17.

DDL : Difference between day-length at the time of flower-bud-formation in plants sown on June 17 and July 17.

Others are the same as mentioned in the previous chapter.

The plants sown on June 17 headed between September 16 and November 23. The plants sown on July 17 headed between October 2 and December 11. Growing periods of plants sown on June 17 and July 17 were observed to be between 90.7 and 159.0 days, 68.3 day-duration, between 77.0 and 147.0 days, 70.0 day-duration, respectively. Differences of growing-period between plants sown on June 17 and July 17 ranged from -2.3 to 28.7 days. Strain showing -2.3-day difference, C8500, showed 3.07 standard deviation in 5 % level ; accordingly, -2.3 days may be negligible. In this strain, the plant sown on July 17 headed 32.3 days later than the plant sown on June 17, when the latter was sown by 30 days delayed than the former, *i. e.*, this strain belongs to photoperiodically insensitive group. It showed a constant length of growing period regardless of day-length. In the opposite extreme case, C7695, the term 28.7 days means that the plant sown on July 17 had 28.7 days shorter growing-period than that sown on June 17, *i. e.*, the former headed only 1.3 days (=30.0-28.7) later than the latter. This strain belongs to photoperiodically sensitive group. Its heading-date was strongly depending upon day-length.

Regression-coefficients of the equations (LRC-1) varied within -0.08 and 0.96. Differences between day-length at the time of flower-bud-formation in plants sown on June 17 and July 17, ranged between 4 and 81 minutes. The regression-coefficients of the equations (LRC-2) varied within the limits of 0.00 and 7.18. These angles varied within 0.0° and 82.1°, *i. e.*, 28 strains were shown within 0° and 10° ; 2 strains, within 11° and 20° ; 3 strains, within 21° and 30° ; 1 strain, within 31° and 40° ; 7 strains, within 41° and 50° ; 5 strains, within 51° and 60° ; 2 strains, within 61° and 70° ; 3 strains, within 71° and 80° ; 1 strain, within 81° and 90°, respectively.

Correspondence between the three different indices of the acceleration-rate is also very good in this experiment.

Apparently, interspecific and intraspecific variations in regard to the acceleration of heading is discontinuous with a gape somewhere. Based on this fact, all strains so far tested could be easily divided into two groups, sensitive and insensitive. The numbers of photoperiodically sensitive strains and insensitive strains were counted to be 22 and 30, respectively. In *O. sativa*, the percentage of sensitive strains is 30.8 % (4/13) in North Borneo ; 10.0 % (2/20) in Brunei, and 100.0 % (3/3) in Sarawak. In *O. officinalis*, LRC-1, LRC-2 and angles varied within 0.21 and 0.89 ; within 0.14 and 5.34 ; within 8.0° and 79.4°, showing very wide range, respectively.

3. *Experiment in 1964*

Forty seven strains belonging to 2 cultivated and 4 wild species were picked up and used in this experiment ; *i. e.*, 3 strains of *O. sativa*, 2 strains of *O. glaberrima*, 18 strains of *O. sativa* var. *spontanea*, 18 strains of *O. perennis*, 5 strains of *O. breviligulata* and 1 strain of *O. latifolia*. In these materials, 4 wild species belong to *Perennis* group, which is closely related to cultivated species. They are considered to be the ancestors of *O. sativa* and *O. glaberrima*, showing very large intraspecific variations in morphological, physiological and genetical characters. This experiment was made mainly to find variations of photoperiodic acceleration-rate in *Perennis* group. Five strains, *i. e.*, 3 of *O. sativa* and 2 of *O. glaberrima*, were used as testers. One strain of *O. latifolia* (W1181 in Table 9) was also used. They are listed in Table 8. Sowing was made repeatedly two times, *i. e.*, on May 17 and on June 16 with 30-days-interval. Some relationships between growing-period, sowing-time and acceleration-rates are shown in Table 9. In this table, the abbreviations used mean the followings ;

DGP : Difference in growing period between plants sown on May 17 and June 16.

DDL : Difference between day-length at the time of flower-bud-formation in plants sown on May 17 and June 16.

Others are the same as mentioned in the experiment made in 1962.

The plants of cultivated species sown on May 17 headed between August 15 and October 25. The plants of cultivated species sown on June 16, headed between September 12 and October 27. Growing-periods of the former were observed to be between 90.0 and 160.7, 70.7 day-duration. Growing-periods of the latter were observed to be between 88.0 and 132.7, 44.7 day-duration. The plants of wild species belonging to *Perennis* group

Table 8. Enumeration of *Oryza* species used in 1964, number of strains used, and their original localities.

Species	No. of strains used	Locality
O. sativa L.	2	Japan
〃	1	Formosa
O. glaberrima STEUD.	2	Africa
O. sativa var. *spontanea* ROSCHEV.	4	India
〃	9	Malaya
〃	1	Ceylon
〃	2	New Guinea
〃	1	Brazil
〃	1	Nepal
O. perennis MOENCH	2	India
〃	2	Burma
〃	2	British Guiana
〃	5	Brazil
〃	1	Colombia
〃	1	New Guinea
〃	1	Java
〃	4	Australia
O. breviligulata CHEV. et ROEHR.	5	Africa
O. latifolia DESV.	1	Panama

Table 9. Acceleration-rates of heading of 47 strains observed by delaying their sowing-time (1964).

Strain	Heading date when sown on		Growing period when sown on		Standard deviation at 5% level	DGP	LRC-1	DDL	LRC-2	Angle (°)	Sensitivity
	5-17	6-16	5-17	6-16							
W0106	10- 6	10-14	142.3	120.3	1.31	22.0	0.73	16	1.37	53.9	S
W0120	10-28	10-31	164.3	137.7	1.31	26.7	0.89	6	4.44	77.3	S
W0139	10- 8	10-13	144.0	119.3	2.93	24.7	0.82	10	2.47	67.9	S
W0157	10- 7	10-20	143.0	126.3	0.93	16.7	0.56	26	0.64	32.6	S
W0574	10-26	10-29	162.3	135.3	2.07	27.0	0.90	6	4.50	77.6	S
W0576	11-16	11-23	182.7	160.3	4.72	22.3	0.72	14	1.54	57.0	S
W0587	10-29	11- 2	165.0	138.7	1.85	26.3	0.88	8	3.29	73.1	S
W0589	11- 9	11- 9	175.7	146.3	2.62	29.3	0.98	0	∞	90.0	S
W0593	10-31	11- 1	166.7	137.7	2.07	29.0	0.97	2	14.50	86.1	S
W0594	10-19	11- 5	155.3	141.7	3.46	13.7	0.45	34	0.40	21.8	S
W0595	11- 4	11-10	171.3	147.0	4.34	24.3	0.81	12	2.03	63.8	S
W0597	10-28	10-30	164.3	136.3	1.38	28.0	0.93	4	6.50	81.3	S
W0605	11- 1	11- 2	167.7	139.3	5.47	28.3	0.95	2	14.20	86.0	S
W0630	9-13	9-21	118.7	97.0	1.85	21.7	0.72	21	1.03	45.8	S
W0635	10-12	10-24	147.7	129.7	1.31	18.0	0.60	36	0.50	26.6	S
W0822	10-14	10-15	150.3	121.0	0.93	29.3	0.98	2	14.65	86.1	S
W0828	10- 7	10-11	143.3	116.7	1.31	26.7	0.89	8	3.33	73.3	S
W0834	9-21	10-11	126.7	117.3	1.31	9.3	0.31	42	0.22	12.4	I
W0840	10-16	10-19	152.3	125.3	1.31	27.0	0.90	6	4.50	77.6	S
W1100	10-21	10-22	157.0	128.3	1.85	28.7	0.96	2	14.35	86.0	S
W1125	9-20	9-24	125.7	100.0	2.45	25.7	0.86	8	3.21	72.7	S
W1161	10- 7	10-19	142.7	125.3	1.31	17.3	0.58	24	0.73	36.0	S
W1181	9-22	10- 9	128.3	115.0	1.85	13.3	0.44	34	0.39	21.3	S
W1183	10-11	10-22	146.7	127.7	1.31	19.0	0.63	22	0.86	40.7	S
W1185	8-26	9-23	100.7	99.0	2.93	1.7	0.06	56	0.03	1.7	I
W1187	10-29	10-31	164.7	136.7	1.31	28.0	0.93	4	7.00	81.9	S
W1188	10-21	10-21	157.0	127.3	4.63	29.7	0.99	0	∞	90.0	S
W1189	8-24	9-21	99.3	97.0	1.31	2.3	0.08	60	0.04	2.3	I
W1191	10-21	10-21	156.7	126.7	3.46	30.0	1.00	0	∞	90.0	S
W1192	11-14	11-21	181.3	157.7	2.07	23.7	0.79	14	1.69	59.4	S
W1196	11- 5	11- 8	172.3	145.3	1.31	27.0	0.90	6	4.50	77.5	S
W1235	11- 1	11- 2	167.7	138.7	1.31	29.0	0.97	2	14.50	86.1	S
W1236	11- 8	11-12	175.0	148.7	3.33	26.3	0.88	10	2.63	69.2	S
W1238	11-19	11-20	186.0	156.7	1.85	29.3	0.98	2	14.65	86.1	S
W1241	9- 8	10- 8	114.3	114.3	1.31	0.0	0.00	60	0.00	0.0	I
W1244	9- 9	10- 6	114.7	112.3	1.31	2.3	0.08	54	0.04	2.3	I
W1288	10-18	10-26	153.7	132.3	2.62	21.3	0.71	16	1.34	53.3	S
W1297	10-17	10-17	153.0	123.3	0.93	29.7	0.99	0	∞	90.0	S
W1298	10-17	10-20	152.7	126.0	0.93	26.7	0.89	6	4.45	77.3	S
W1299	10-16	10-17	152.3	122.7	1.31	29.7	0.99	2	14.80	86.2	S
W1300	10-19	10-20	155.0	126.0	2.78	29.0	0.97	2	14.50	86.1	S
W1347	10-17	10-29	152.7	135.3	1.31	17.3	0.58	24	0.73	36.1	S
C7692	10-19	10-22	155.3	127.7	1.31	27.7	0.92	6	4.60	77.7	S
C7695	10-25	10-27	160.7	132.7	1.31	28.0	0.93	4	7.00	81.9	S
647	9- 3	10- 1	109.0	107.0	0.00	2.0	0.07	60	0.03	1.8	I
108	8-15	9-12	90.0	88.0	1.60	2.0	0.07	56	-0.04	2.3	I
KA	9- 7	9-18	113.3	94.3	1.31	19.0	0.63	22	0.86	40.7	S

sown on May 17 headed between August 24 and November 19. The plants of wild species belonging to *Perennis* group sown on June 16, headed between September 21 and November 23. Growing-periods of the former were observed between 99.3 and 186.0 days, 86.7 day-duration. Growing-periods of the latter were observed to be between 97.0 and 160.3 days, 63.3 day-duration.

Differences of growing-period of cultivated species sown on May 17 and June 16 ranged from 2.0 to 28.0 days. Differences of growing-period of wild species belonging to *Perennis*-group sown on May 17 and June 16, ranged from 0.0 to 30.0 days. In the strain showing 0.0 day, the plant sown on June 16 headed 30 days later than that sown on May 17. This strain belongs to photoperiodically insensitive group. In the strain showing 30.0 days, the plant sown on June 16 had 30.0 shorter growing period than that sown on May 17, *i. e.*, the former and the latter had headed in the same day, nevertheless the latter was sown on 30 days more delayed than the former. This strain belongs to photoperiodically sensitive group.

Regression-coefficients of the equations (LRC-1) of cultivated species varied within 0.07 and 0.93. Differences between day-length at the time of flower-bud-formation in plants sown on May 17 and June 16, ranged between 4 and 60 minutes. The regression-coefficients of the equations (LRC-2) of cultivated species varied widely within 0.03 and 7.00. The angles varied within 1.8° and 81.9°.

Regression-coefficients of the equations (LRC-1) of wild species belonging to *Perennis*-group varied within 0.00 and 1.00. Differences between day-length at the time of flower-bud-formation in plants sown on May 17 and June 16 ranged within 0 and 60 minutes. The regression-coefficients of the equations (LRC-2) of wild species belonging to *Perennis*-group, varied widely within the limits of 0.00 and infinite. The angles varied within 0.0° and 90.0°, *i. e.*, 4 strains were shown within 0° and 10°; 1 strain, within 11° and 20°; 2 strains, within 21° and 30°; 4 strains, within 31° and 40°; 1 strain, within 41° and 50°; 4 strains, within 51° and 60°; 3 strains, within 61° and 70°; 8 strains, within 71° and 80°; 14 strains, within 81° and 90°, respectively.

Correspondence between the three different indices of the acceleration-rate is also very good in this experiment.

In *O. sativa* var. *spontanea*, frequency of photoperiodically sensitive strains was 88.9 % (16/18) in the whole, *i. e.*, 100.0 % (4/4) of the strains found in India; 100.0 % (9/9), in Malaya; 100.0 % (1/1), in Ceylon; 100.0 % (2/2), in New Guinea; 0.0 % (0/1), in Brazil, and 0.0 % (0/1), in Nepal. The angles varied within 0.0° and 86.1° in the whole strains; *i. e.*, 32.6° and 86.0°, in India; 21.8° to 86.0°, in Malaya; 36.0°, in Ceylon; 86.1°, in New Guinea; 0.0°, in Brazil; 2.3°, in Nepal. In *O. perennis*, the frequency of photoperiodically sensitive strains was 88.9 % (16/18) in the whole strains, *i. e.*, 100.0 % (2/2) of the strains found in India; 100.0 % (2/2), in Burma; 50.0 % (1/2), in British Guiana; 80.0 % (4/5), in Brazil; 100.0 % (1/1), in Colombia; 100.0 % (1/1), in New Guinea; 100.0 % (1/1), in Java; 100.0 % (4/4), in Australia. The angles varied within 1.7° and 90.0° in the whole strains, *i. e.*, 72.7° and 77.3°, in India; 26.6° and 45.8°, in Burma; 1.7° and 40.7°, in British Guiana; 2.3° and 90.0°, in Brazil; 77.5°, in Colombia; 69.2°, in New Guinea; 53.3°, in Java; 77.3° and 90.0°, in Australia. In *O. breviligulata*, frequency of photoperiodically sensitive strains was 80.0 % (4/5), and their angles varied within 12.4° and 86.1°.

The strain of *O. latifolia* used, belongs to photoperiodically sensitive group, showing the angle as 21.3°.

4. *Experiment in 1966*

Fifty six strains belonging to 5 different wild species, which have all A-genome alone, and are taxonomically closely related to the cultivated species, were picked up and used in this experiment, *i. e.*, 20 strains of *O. sativa* var. *spontanea* distributed only in Asia, 20 strains of *O. perennis*, 3 strains of *O. barthii*, 3 strains of *O. stapfii* and 10 strains of *O. breviligulata*. The plants of the latter three species, were distributed only in Africa. In this experiment, main object was, continuously from the previous year, to find the photoperiodical interspecific and intraspecific variations in wild species belonging to *Perennis* group. They are listed in Table 10. A relationships between growing-period and sowing-time and acceleration-rate are shown in Table 11. In this table, the abbreviations mean the followings ;

DGP : Difference in growing-period between plants sown on May 17 and June 16.

DDL : Difference between day-length at the time of flower-bud-formation in plants sown on May 17 and June 16.

Others are the same as mentioned in the experiment made in 1962.

The plants sown on May 17 headed between September 13 and November 11. The plants sown on June 16 headed between September 21 and November 28. Growing periods of the former were observed to be between 119.3 and 178.3 days, 59.0 day-

Table 10. Enumeration of *Oryza* species used in 1966, number of strains and their original localities.

Species	No. of strains used	Locality
O. sativa var. *spontanea* ROSCHEV.	8	India
〃	1	Thailand
〃	1	South China
〃	4	Malaya
〃	5	Burma
〃	1	New Guinea
O. perennis MOENCH	3	India
〃	3	Thailand
〃	2	Brazil
〃	5	Burma
〃	2	New Guinea
〃	1	Java
〃	1	Kalimantan
〃	3	Australia
O. barthii CHEV. et ROEHR.	3	Africa
O. stapfii ROSCHEV.	3	Africa
O. breviligulata CHEV. et ROEHR.	10	Africa

Table 11. Acceleration-rates of heading of 56 strains observed by delaying their sowing-time (1966).

Strain	Heading date when sown on		Growing period when sown on		Standard deviation at 5% level	DGP	LRC-1	DDL	LRC-2	Angle (°)	Sensitivity
	5-17	6-16	5-17	6-16							
W0009	9-30	9-30	135.7	106.3	1.29	29.3	0.98	0	∞	90.0	S
W0031	11- 2	11- 6	168.7	142.7	6.54	26.0	0.89	18	3.10	72.1	S
W0036	11- 4	11- 4	171.0	141.3	0.92	29.7	0.99	0	∞	90.0	S
W0042	9-28	9-30	134.3	106.0	0.92	28.3	0.94	1	25.73	87.8	S
W0105	10- 6	10-11	142.3	117.0	2.45	25.3	0.84	11	2.41	67.5	S
W0106	10-11	10-14	146.7	120.3	1.29	26.3	0.88	6	4.19	76.6	S
W0107	10-14	10-16	150.3	122.3	1.29	28.0	0.93	4	6.67	81.4	S
W0120	11- 6	11- 8	173.3	145.0	2.05	28.3	0.94	4	6.43	81.2	S
W0121	10-20	10-25	156.0	131.0	3.58	25.0	0.83	11	2.27	66.3	S
W0122	10-25	10-24	161.0	130.0	1.61	31.0	1.03	0	∞	90.0	S
W0124	10-30	11- 5	165.7	142.3	1.29	23.3	0.78	13	1.85	61.6	S
W0125	10-22	10-22	158.0	128.3	0.92	29.7	0.99	0	∞	90.0	S
W0126	10-23	10-23	159.3	129.3	3.07	30.0	1.00	0	∞	90.0	S
W0130	10-26	10-26	162.0	132.0	1.61	30.0	1.00	0	∞	90.0	S
W0162	10-29	11- 1	164.7	137.7	4.72	27.0	0.90	6	4.29	76.9	S
W0170	10-16	10-16	152.0	122.3	1.85	29.7	0.99	0	∞	90.0	S
W0174	11- 3	11- 3	170.3	140.3	2.62	30.0	1.00	0	∞	90.0	S
W0176	11- 5	11- 7	172.3	144.3	1.29	28.0	0.93	4	6.51	81.3	S
W0552	10-19	10-27	154.7	132.7	4.44	22.0	0.73	18	1.25	51.4	S
W0587	11- 5	11- 6	172.3	142.7	1.29	29.7	0.99	2	14.14	86.0	S
W0593	11- 1	11- 1	168.0	138.3	0.92	29.7	0.99	0	∞	90.0	S
W0596	11- 1	11- 6	168.0	143.3	0.92	24.7	0.81	11	2.35	67.0	S
W0598	10-28	10-31	164.3	137.0	2.63	27.3	0.91	6	4.33	77.0	S
W0608	11-10	11-12	176.7	148.7	2.62	28.0	0.93	4	6.36	81.2	S
W0610	10-16	10-22	152.3	127.7	1.29	24.7	0.82	13	1.89	62.1	S
W0612	11-11	11-28	178.3	165.0	0.92	13.3	0.44	25	0.53	28.0	S
W0619	10-22	10-23	158.3	129.0	2.45	29.3	0.98	2	13.32	85.8	S
W0622	10-24	10-29	160.3	134.7	2.62	25.7	0.86	11	2.38	67.2	S
W0623	10-23	10-23	159.3	129.3	2.62	30.0	1.00	0	∞	90.0	S
W0627	10-31	11- 2	167.7	139.0	4.34	28.7	0.96	26	1.11	48.0	S
W0630	9-13	9-21	119.3	97.0	1.85	22.3	0.74	16	1.41	54.7	S
W0631	10-23	10-24	158.7	130.3	2.62	28.3	0.94	2	12.86	85.6	S
W0632	11- 5	11- 7	172.0	144.0	2.78	28.0	0.93	4	6.51	81.3	S
W0633	10-11	10-16	146.7	121.7	1.61	25.0	0.83	11	2.38	67.2	S
W0636	10-25	10-30	160.7	136.3	3.07	24.3	0.81	11	2.27	66.2	S
W0652	10-23	10-24	158.7	130.0	2.45	28.7	0.96	2	13.05	85.6	S
W0665	11- 2	11- 2	169.3	138.7	1.29	30.7	1.00	0	∞	90.0	S
W0677	10-20	11- 2	166.0	138.7	1.85	27.3	0.91	4	6.50	81.3	S
W0721	10- 1	10-26	137.0	132.0	3.58	5.0	0.17	113	0.04	2.5	I
W0771	11- 9	11- 9	175.7	145.7	1.29	30.0	1.00	0	∞	90.0	S
W0825	10-19	10-20	155.3	126.3	3.46	29.0	0.97	2	13.18	85.7	S
W0827	11- 4	11- 6	170.7	142.7	1.29	28.0	0.93	4	6.67	81.6	S
W0831	11- 2	11- 2	168.7	138.7	1.29	30.0	1.00	0	∞	90.0	S
W0842	11- 8	11- 9	175.3	145.7	1.29	29.7	0.99	2	13.50	85.8	S
W0849	11- 8	11- 9	175.3	145.7	1.29	29.7	0.99	2	13.50	85.8	S
W0887	11- 7	11-10	174.3	147.3	2.82	27.0	0.90	7	4.09	76.3	S

(*Continued on page* 312)

Table 11. (Continued)

W1045	10-22	11- 2	158.3	138.7	3.66	19.7	0.67	25	0.80	38.7	S
W1054	10-20	10-31	166.0	137.3	0.92	28.7	0.96	2	13.67	85.8	S
W1230	11- 8	11-10	174.7	146.7	1.29	28.0	0.93	4	6.36	81.1	S
W1236	10-23	10-31	159.0	137.0	1.61	22.0	0.73	17	1.28	52.0	S
W1238	11- 3	11- 7	170.0	144.3	0.92	25.7	0.86	9	3.02	71.7	S
W1288	10-17	10-21	153.0	127.3	4.03	25.7	0.86	9	2.92	71.1	S
W1292	11- 5	11-10	172.0	147.0	1.22	25.0	0.83	11	2.29	66.5	S
W1297	10-17	10-21	153.3	127.3	1.29	26.0	0.89	9	2.96	71.3	S
W1299	10-22	10-23	158.3	128.7	1.29	29.7	0.98	2	13.32	85.8	S
W1300	10-22	10-23	158.0	128.7	1.85	29.3	0.98	2	13.32	85.8	S

duration. Growing periods of the lattter were observed to be between 97.0 and 165.0 days, 68.0 day-duration.

Differences of growing-period sown on May 17 and June 16, ranged from 5.0 to 31.0. In the strain showing 5.0 days, the plant sown on June 16 headed 25 days (=30.0−5.0) later than that sown on May 17. This strain belongs to photoperiodically insensitive group. Strain showing 31.0 day-difference showed 1.61 standard-deviation at 5 % level. Hence, 1.0 (=31.0−30.0) day may be negligible. In this strain, the plants sown on May 17 and June 16 headed at the same time. This strain belongs to photoperiodically sensitive group. Its heading date was strongly depending upon day-length.

Regression-coefficients of the equations (LRC-1) varied within 0.17 and 1.03. Differences between day-length at the time of flower-bud-formation in plants sown on May 17 and June 16, ranged between 0 and 113 minutes. The regression-coefficients of the equations (LRC-2) varied widely within the limits of 0.04 and infinite. The angles varied within 2.5° and 90.0°, *i. e.*, 1 strain was shown within 0° and 10°; 1 strain, within 21° and 30°; 1 strain, within 31° and 40°; 1 strain, within 41° and 50°; 3 strains, within 51° and 60°; 9 strains, within 61° and 70°; 8 strains, within 71° and 80°; 32 strains, within 81° and 90°, respectively.

Correspondence between the three different indices of the acceleration-rate is very good also in this experiment.

Although the strains of wild species belonging to *Perennis* group are distributed in quite different parts of the world, they showed a very similar photoperiodic response, *i. e.*, all of them contained almost exclusively sensitive strains (98.2 %, 55/56). Only one strain belonging to *O. barthii*, found in Bamako, Sudan (13° N), was insensitive, showing 2.5° in the angle.

The angles were found between 2.5° and 90.0° in the whole strains as mentioned above. The angles of *O. sativa* var. *spontanea* were found to be between 51.4° and 90.0° in the whole strains, *i. e.*, 61.6° and 90.0°, in India; 90.0°, in Thailand; 51.4°, in South China; 67.0° and 90.0°, in Malaya; 62.1° and 90.0°, in Burma; and 71.7°, in New Guinea. The angles of *O. perennis* were found between 28.0° and 90.0° in the whole strains, *i. e.*, 66.3° and 81.2°, in India; 76.9° and 90.0°, in Thailand; 28.0° and 90.0°, in Brazil; 48.0° and 81.3°, in Burma; 52.0° and 81.1°, in New Guinea; 71.1°, in Java; 66.5°, in Kalimantan; 71.3° and 85.8°, in Australia. The angles of *O. barthii* were found to be between 2.5° and 90.0°. The angles of *O. stapfii* were found to be between 81.2° and 85.8°. The angles of *O. breviligulata* were found to be between 76.3° and 90.0°.

Discussion

HARA (2) calculated the degree of sensitivity, on the basis of its coefficient by some formula. Generally speaking, the sensitivity-coefficients of early varieties were smaller than those of later varieties. He concluded that the lower is the latitude of the habitat, the weaker is the sensitivity. The writer investigated, in the previous paper (5), using 68 strains belonging to different *Oryza* species, the sensitivity and obtained a quite different results ; that is, a strain grown in a low latitude could show a large acceleration rate of heading. The following two reasons may be conceived for explaining the discrepancy found in these two papers. Firstly, the sensitivity-coefficient calculated by HARA (2) is based on the growing-periods of plants raised under natural and 8 hour days, the latter never occurring in natural localities of rice cultivation. Therefore, a real response cannot be revealed under such an extremely short day-length. Secondly, it is uncertain whether its insensitive strains were excluded from the calculation of the relationship between the degree of sensitivity and the latitude of habitat. Data obtained from the insensitive strains should be omitted for the calculation of degree of sensitivity.

In the previous paper (5), several problems were left unsolved, that is, 1) whether these calculation-methods are used as universal validity for wider strains and species or not, 2) whether the values shown by these methods are stable or unstable in accordance with the respective year, 3) whether there are or not the species specific variations in the degree of sensitivity shown by these methods, 4) whether the values shown by these methods are stable or unstable according to the sowing time. As the explanation of these problems was left, the present investigations were done, and showed some solution, to certain extent, for each problem mentioned above.

Even in the same strain, the acceleration-rates shown by these methods used in this paper, are clearly not quite the same through the respective year. Then, the acceleration-rates of 17 strains belonging to the four different species, *i. e.*, 1 strain of *O. sativa*, 1 strain of *O. glaberrima*, 7 strains of *O. sativa* var. *spontanea* and 8 strains of *O. perennis*, were picked up from the data obtained in 1962, 1963, 1964 and 1966 shown in the Tables 5, 7, 9 and 11, respectively, and shown in Table 12. The abbreviations used in this table mean the characters explained in the experiment made in 1962 Whole of them shown belong to photoperiodically sensitive group.

In general, most of strains showed the similar data in the values of LRC-1, LRC-2 and the angle, nevertheless the sowing time was different in accordance with the respective year.

In the same strain, the differences of regression-coefficient (LRC-1) according to the year, varied within the limits of 0.01 and 0.33, but 76.5 % (13/17) strains of their materials varied within only 0.01 and 0.17. In the same strain, the differences of the angle of regression-coefficient, according to the year varied within 0.2° and 54.3°, but 70.6 % (12/17) strains of these materials varied within only 0.2° and 19.4°. These phenomena showed that the photoperiodic sensitivity shown by the methods used might be said to be relatively stable notwithstanding the year.

To make clear this relationship, the 27 strains belonging to 5 different species, *i. e.*, 4 strains of *O. sativa*, 1 strain of *O. glaberrima*, 11 strains of *O. sativa* var. *spontanea*,

Table 12. Comparison of acceleration-rates of heading of 17 strains observed during the period from 1962 to 1966.

Strain	Year	Heading date when sown on				Growing period when sown on				DGP	LRC-1	DDL	LRC-2	Angle (°)
		4-17	5-17	6-16 or 6-17	7-16 or 7-17	4-17	5-17	6-16 or 6-17	7-16 or 7-17					
W0106	1964	-	10- 6	10-14	-	-	142.3	120.3	-	22.0	0.73	16	1.37	53.9
	1966	-	10-11	10-14	-	-	146.7	120.3	-	26.3	0.88	6	4.19	76.6
W0120	1963	-	-	10-23	10-31	-	-	127.7	106.0	21.7	0.72	17	1.25	51.3
	1964	-	10-28	10-31	-	-	164.3	137.7	-	26.7	0.89	6	4.44	77.3
	1966	-	11- 6	11- 8	-	-	173.3	145.0	-	28.3	0.94	4	6.43	81.2
W0157	1962	10-20	10-24	10-29	-	186	160	135	-	51	0.85	20	2.55	68.6
	1964	-	10- 7	10-20	-	-	143.0	126.3	-	16.7	0.56	26	0.64	32.6
W0587	1964	-	10-29	11- 2	-	-	165.0	138.7	-	26.3	0.88	8	3.29	73.1
	1966	-	11- 5	11- 6	-	-	172.3	142.7	-	29.7	0.99	2	14.14	86.0
W0593	1964	-	10-31	11- 1	-	-	166.7	137.7	-	29.0	0.97	2	14.50	86.1
	1966	-	11- 1	11- 1	-	-	168.0	138.3	-	29.7	0.99	0	∞	90.0
W0630	1964	-	9-13	9-21	-	-	118.7	97.0	-	21.7	0.72	21	1.03	45.8
	1966	-	9-13	9-21	-	-	119.3	97.0	-	22.3	0.74	16	1.41	54.7
W0635	1962	10-22	10-24	10-26	10-29	188	160	132	105	56	0.93	9	6.22	80.9
	1964	-	10-12	10-24	-	-	147.7	129.7	-	18.0	0.60	36	0.50	26.6
W1100	1962	10-19	10-20	10-25	10-27	185	156	131	103	54	0.90	13	4.15	76.5
	1964	-	10-21	10-22	-	-	157.0	128.3	-	28.7	0.96	2	14.35	86.0
W1235	1963	-	-	11- 1	11-10	-	-	137.3	116.3	21.0	0.70	19	1.11	48.0
	1964	-	11- 1	11- 2	-	-	167.7	138.7	-	29.0	0.97	2	14.50	86.1
W1236	1964	-	11- 8	11-12	-	-	175.0	148.7	-	26.3	0.88	10	2.63	69.2
	1966	-	10-23	10-31	-	-	159.0	137.0	-	22.0	0.73	17	1.28	52.0
W1238	1964	-	11-19	11-20	-	-	186.0	156.7	-	29.3	0.98	2	14.65	86.1
	1966	-	11- 3	11- 7	-	-	170.0	144.3	-	25.7	0.86	9	3.02	71.7
W1288	1964	-	10-18	10-26	-	-	153.7	132.3	-	21.3	0.71	16	1.34	53.3
	1966	-	10-17	10-21	-	-	153.0	127.3	-	25.7	0.86	9	2.92	71.1
W1297	1964	-	10-17	10-17	-	-	153.0	123.3	-	29.7	0.99	0	∞	90.0
	1966	-	10-17	10-21	-	-	153.3	127.3	-	26.0	0.89	9	2.96	71.3
W1299	1964	-	10-16	10-17	-	-	152.3	122.7	-	29.7	0.99	2	14.80	86.2
	1966	-	10-22	10-23	-	-	158.3	128.7	-	29.7	0.98	2	13.32	85.8
W1300	1964	-	10-19	10-20	-	-	155.0	126.0	-	29.0	0.97	2	14.50	86.1
	1966	-	10-22	10-23	-	-	158.0	128.7	-	29.3	0.98	2	13.32	85.8
Kyoto Asahi	1963	-	-	9-16	10- 2	-	-	90.7	77.0	13.7	0.46	35	0.39	21.3
	1964	-	9- 7	9-18	-	-	113.3	94.3	-	19.0	0.63	22	0.86	40.7
C7695	1963	-	-	10-29	10-30	-	-	133.7	105.0	28.7	0.96	4	7.18	82.1
	1964	-	10-25	10-27	-	-	160.7	132.7	-	28.0	0.93	4	7.00	81.9

9 strains of *O. perennis*, 2 strains of *O. breviligulata*, were picked up. Two strains of them, *i. e.*, 108 and 647, belong to photoperiodically insensitive group and other 25 strains belong to photoperiodically sensitive group. These data shown were obtained and calculated from Tables 5, 7, 9, 11 and the previous paper (5), and after being compared with the acceleration-rate of heading expressed by angle converted from LRC-2 values, were shown in Table 13. In this table, the data shown in the previous paper (5) and in the present experiments were shown at first and secondly the differences of the angles observed in the respective year, were shown in the two groups, *i. e.*, the comparative differences between the data obtained in the previous paper and in the present experiment and differences within the present experiment.

Firstly, the comparison were done separately on the between-group and within-group. In comparison of the between-group, 41.2 % (7/17) of the whole cases showed the differences between 0° and 10°; 35.3 % (6/17), between 11° and 20°; 5.9 % (1/17), between 21° and 30°; 5.9 % (1/17), between 31° and 40°, and 11.8 % (2/17) in 42°; that is, 76.5 % (13/17) of the whole cases showed the differences lying only between 0° and 20°.

Table 13. Differences of acceleration-rates of heading expressed by the angles of 27 strains (1961 to 1966) (°).

Strain	Angles found in					Differences of angles found in the respective year: between 1961 and				Differences of angles found in the respective year: within the present experiment			
	1961*	1962	1963	1964	1966	1962	1963	1964	1966	1962 and 1964	1963 and 1964	1963 and 1966	1964 and 1966
Kyoto Asahi	44		21	41			23	3			20		
108	4			2				2					
124	68	63				5							
647	10			2				8					
C7695			82	82							0		
W0009	70				90				20				
W0042	70				88				18				
W0106	35			54	77			19	42				23
W0107	43				81				38				
W0120	67		51	77	81		16	10	14		26	30	4
W0121	66				66				0				
W0124	57				62				5				
W0125	76				90				14				
W0126	48				90				42				
W0157		69		33						36			
W0587				73	86								13
W0593				86	90								4
W0630				46	55								9
W0635		81		27						54			
W1100		77		86						9			
W1235			48	86							38		
W1236				69	52								17
W1238				86	72								14
W1288				53	71								18
W1297				90	71								19
W1299				86	86								0
W1300				86	86								0

* Obtained from the previous paper (5).

In the comparison of within-group, 36.8 % (7/19) of the whole cases showed the differences between 0° and 10°; 31.6 % (6/19), between 11° and 20°; 15.8 % (3/19), between 21° and 30°; 10.5 % (2/19), between 31° and 40°, and 5.3 % (1/19) in 54°; that is, 68.4 % (13/19) of the whole cases showed the differences only lying between 0° and 20°. There was not a clear differences in between- and within-group.

As there was no clear difference in between- and within-group; secondly, the data obtained in both group, were calculated together. In the comparison done in both between- and within-group, 38.9 % (14/36) of the whole cases showed the differences between 0° and 10°; 33.3 % (12/36), between 11° and 20°; 11.1 % (4/36), between 21° and 30°; 8.3 % (3/36), between 31° and 40°; 5.6 % (2/36) in 42°, and 2.8 % (1/36) in 54°; that is, 72.2 % (26/36) of the whole cases, about three fourth of the whole cases, showed the differences only lying between 0° and 20°.

Generally speaking, differences calculated between 1961 and 1964, and differences between 1964 and 1966, showed very small degree. Kyoto Asahi, a *japonica* type strain of *O. sativa*, showed the angles of 43.8° in the previous paper; 21.3° in 1963, and 40.7° in 1964; respectively. On the contrary, C7695, a strain of *O. glaberrima*, showed the quite the same angles of 82.1° in 1963 and 81.9° in 1964, respectively. However, in general, some consistent relation was found in the whole cases between the angles obtained in some year and an other year, which showed the acceleration-rates of the heading brought forth by delaying the sowing time. There was a significant correlation between them ($\gamma = 0.6215^{***}$, d. f.=34) at 0.1 % level. It is true that a strain showing large angle value in one year, shows relatively large value every year; *i. e.*, the acceleration-rate might be relatively stable in the plant belonging to the genus *Oryza*, as one of the fundamental physiological characters; in other words, such strain shows high stability for photoperiodic sensitivity.

It may not be neglected that the angle values varied widely according to the respective year. Some meteorological characters, such as temperature, relative humidity, might well be considered in explaining this flexibility. Some strains, including photoperiodically sensitive and insensitive strains, were well studied during the several years, and its acceleration-rate and degree of flexibility were made clear. For example, Kyoto Asahi, a sensitive strain of a *japonica* type of *O. sativa*, showed the angles of 21.3° in 1963 and 40.7° in 1964, respectively; as mentioned before. 108, an insensitive strain of a *indica* type of *O. sativa*, showed the angles of 4.1° in the previous paper, and 2.3° in 1964, respectively. In the previous paper (5), it was mentioned that the strain having an angle larger than 30° may be considered to be sensitive, and strain having a smaller angle than 30°, to be insensitive. Because of the flexibility mentioned above, however, such border-line between the two groups was 20° in 1963.

In Kyoto Asahi, LRC-1 and LRC-2 were shown as 0.65 and 0.96 in the previous paper, respectively. But they were shown to be 0.46 and 0.39 in 1963 and 0.63 and 0.86 in 1964; respectively. In the previous paper, it was mentioned that strains having LRC-1 and LRC-2 larger than 0.5 might be considered to be sensitive and that having a smaller LRC-1 and LRC-2 than 0.5, to be insensitive. Because of the flexibility mentioned above, however, such border-lines between the two groups were 0.35 in 1963 and 0.50 in 1964, respectively.

From the reasons mentioned above, day-length during the experimental period or the latitude, in which the experiment was done, should expressively be stated. If experiments were done in several latitudes, the values expressed by the methods may be varied, showing some tendency. This problem will be investigated in future. The author would like to make a proposing suggestion that such strains, in which the acceleration-rate was clear in the given locality, are to be used as a certain set of test strains every year, and then the border-line between the two groups (photoperiodically sensitive and insensitive groups) of LRC-1, LRC-2 and the angles should be decided in the respective year.

In the experiment of 1963, eleven strains showed minus quantity in the differences of growing-period and of linear regression-coefficient expressed by LRC-1 (Table 7). It is presumable that the germination and growth in the early stage of plant, was disturbed by high temperature in sowing at midsummer, and the growing-period was prolonged in this year. In this case, the strain had the standard deviation, at 5 % level, larger than their minus quantity. Then, it may be clearly negligible, but it is recommended that sowing at midsummer was to be avoided for this experiment.

In the angle value, 90.0° were found 23.1 % (6/26) strains used in the experiment in 1962 ; 0.0 % (0/52), in 1963 ; 8.5 % (4/47), in 1964 and 23.2 % (13/56) in 1966 ; respectively. Such differences occurred, of course, according to the different strains, but presumably in accordance with some meteorological conditions more than that.

In photoperiodically sensitive strains, the acceleration-rates of heading obtained by delaying their sowing, expressing LRC-1, LRC-2 and the angle, varied, in general, flexibly in each case ; in which comparisons were done with different sowing-time. For example, LRC-1 of W1100, a strain of *O. sativa* var. *spontanea* found in India, was shown to be 0.97, 0.90, 0.91, 0.83, 0.88 and 0.93, when the comparisons were done by the data of plants sown on April 17 and May 17 ; on April 17 and June 16 ; on April 17 and July 16, on May 17 and June 16 ; on May 17 and July 16 ; on June 16 and July 16. respectively (calculated from data, shown in Table 5). As another example in the previous paper (5), LRC-1 of Kyoto Asahi, a *japonica* type of *O. sativa* found in Japan, was shown to be 0.55, 0.68, 0.65, 0.30, 0.50 and 0.70, when the comparisons were done by the data of plants sown on May 10 and May 30; on May 10 and June 19 ; on May 10 and July 9 ; on May 30 and June 19 ; on May 30 and July 9 ; on June 19 and July 9 ; respectively. No ascertainment was done, as some tendency, that the longer is the difference of the period of sowing-time, the smaller or the larger is the flexibility.

It is an important finding that strains having larger values in LRC-1, LRC-2 and the angle showed, in general, the smaller flexibility than those having smaller values. In other word, the higher is the sensitivity, the smaller is the flexibility, as it is expressed by LRC-1, LRC-2 and the angle.

The standard deviations, at 5 % level, of the growing-period were found to be between 0.93 and 7.17 in 1963 ; between 0.00 and 5.47, in 1964 ; between 0.92 and 4.72, in 1966 ; respectively. Generally speaking, the smaller is the standard deviation, the higher is the stability, as it was expressed by the flexibility of LRC-1, LRC-2 and by the angle in the different year and in the different sowing-time. It is also presumable that strain, having genetically homozygous constitution, showed the smaller standard deviation of growing-period than those having heterozygous constitution.

Judging from several morphological and physiological characteristics of *O. of-*

ficinalis found in Borneo, it was assumed that *O. officinalis* might have originated in Borneo or its adjacent island, and that photoperiodically sensitive strains of this species might be the original form from which insensitive strains have derived (6). *O. officinalis* in Borneo showed high frequency of sensitive strains (75 %). BUTANY *et al.* (1) showed also that wide variations in photoperiodic response were found in *O. officinalis.* As shown in Table 7, the acceleration-rate of heading obtained by delaying the sowing time of *O. officinalis* varied widely within the limits of 6.3 and 26.7 in the differences of growing-period (DGP) ; within 0.21 and 0.89 in LRC-1 ; within 0.14 and 5.34 in LRC-2 ; within 8.0 and 79.4 in the angle ; respectively. Three strains of them belong to photoperiodically insensitive group, and other nine strains of them belong to photoperiodically sensitive. It is clear that *O. officinalis* showed very wide intraspecific variations on the acceleration-rate of photoperiodic sensitivity similar to the other morphological and physiological characters mentioned before.

The lower was, in general, the latitude of habitat, the larger was the acceleration-rate, shown by LRC-1, LRC-2 and the angle. No definite relationship was found between the taxonomic status and sensitivity. This may be due to a fact that the degree of photoperiodic sensitivity, such as the critical day-length and aging-effect (4), or the acceleration-rate of heading is primarily determined by the latitude. This fact may be distinctly interpreted as follows ; the lower is the latitude, the more days are necessary in the change of the natural day-length. Consequently, a strain having a high photoperiodic sensitivity, such as acceleration-rate of heading (namely, a large angle of the regression line) which is able to respond to a small change of natural day-length at low latitude may be favoured in the struggle for existence. However, as shown in Table 7, many insensitive strains of cultivated rice will be prevailing in some extremely tropical countries. SCRIPCHINSKY (7) considered that the natural change in day-length does not cause photoperiodic reaction of plants native to the tropical regions. Therefore, it is noteworthy that some photoperiodically sensitive strains of cultivated and wild species are found in the equatorial regions (Tables 7, 9 and 11), where the difference of day-length throughout the year is very slight, with sensitivity which appears to be meaningless. Their behaviour may be interpreted as follows ; those strains were originated in northern or southern areas, where the difference of day-length throughout the year is conspicuous, and migrated to equatorial habitats. Indeed, it was found in Southern New Guinea that one of the large population of *Oryza perennis* was floating and carried away to long distance in Koembe River (3). It is presumable that such migration behaviour is one of the most important methods in which the plant was differentiated and spread their population size, including photoperiodically sensitive and insensitive strains.

Judging from several characteristics mentioned above, it is trustworthy that photoperiodic sensitivity shown by biological index, such as acceleration-rate of heading was differentiated and determined in strain specific level, according to the natural conditions, regardless of the species and of the genome-constitution, allowing them to have a selective advantage in the struggle for existence.

Summary

In the present investigation, the difference in photoperiodic sensitivity was analysed from some viewpoint, namely, from the differential acceleration-rate of heading among various strains. One hundred and sixty three strains belonging to 9 species of the genus *Oryza*, including 2 cultivated and 7 wild species, were used in the present experiment. The experiment were done during four years, in which strains differing from one another were used.

Frequency of photoperiodically sensitive strains used in this experiment was 27.5 % (11/40) in *O. sativa*; 100.0 % (2/2) in *O. glaberrima*; 95.7 % (44/46) in *O. sativa* var. *spontanea*; 95.0 % (38/40) in *O. perennis*; 66.7 % (2/3) in *O. barthii*; 100.0 % (3/3) in *O. stapfii*; 93.3 % (14/15) in *O. breviligulata*; 76.9 % (10/13) in *O. officinalis*; 100.0 % (1/1) in *O. latifolia* and 76.7 % (125/163) in the whole strains. In the whole strains, a great majority were photoperiodically sensitive. This indicates that sensitive strains are, in general, favoured under natural as well as artificial selections.

Indices of the acceleration-rate used, were three methods; *i. e.*, coefficient of linear regression of growing-period on sowing-time (expressed by LRC-1), coefficient of linear regression of growing-period on day-length at the time of flower-bud-formation (expressed by LRC-2), and angle changed from the latter coefficient (expressed by the angle). The regression-coefficients of equations (LRC-1)varied within 0.00 and 1.00. The regression-coefficients of the equations (LRC-2) varied from 0.00 to infinite. The angles varied between 0.0° and 90.0°.

Coincidence between three indices was very good in every year, all fitting well the previous classification of strains in sensitive and insensitive (4). Border-lines between the two groups were flexible for LRC-1, LRC-2 and the angle according to the respective year and sowing-time. Then, it would be proposed suggestively that the strain or strains, in which its acceleration-rate was clear, are used as a test-strain every year, and then the border-line of the respective index and of the respective year between sensitive and insensitive strains would be decided. It is recognized that the strains having large values in the indices used, showed, in general, the smaller flexibility than those having smaller values. In other word, the higher is the sensitivity, the smaller is the flexibility. *O. officinalis* showed very wide intraspecific variation on the acceleration-rate of photoperiodic sensitivity similar to the other morphological and physiological characters mentioned before. Several articles were discussed from the physiological and phylogenetical view-point.

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