CHARACTERISTICS OF THE CHANGE OF TEMPERATURE IN RICE PLOTS OF VARIOUS DENSITIES

by

DR. ILONA BÁRÁNY and DR. J. BOROS

In rice-growing areas possessing different climatic features, the study of the microclimatic conditions of the rice plots is an important task. In addition to its theoretical significance, the practical importance of this is proved by the works of M. ZHAPBASBAEV (1969), V. K. VAMADEVAN (1971), N. P. KRASNOOK—V. PTASHKIN—Y. A. VISHNAKOVA (1971) and R. WAGNER (1966) referring to the correlation of the yield results and the climatic factors.

In our treatment, the microclimatic studies performed at Szarvas in 1971 under the direction of R. WAGNER were used as the basis of a comparison of the air and water temperatures of two rice plots of identical sowing density: a dense plot, which had been heavily treated with artificial fertilizer, and a rare plot, which had not been fertilized. The comparison was made using the extreme temperatures, the relative temperatures and the trigonometrical polynomials of the temperatures of the various levels.

The phenophases of the two plots in the months of July and August were as follows:

	Tillering	Development of stems	Development of panicles and flowering
Dense plot	Jul. 1—Jul. 21	Jul. 22—Aug. 1	Aug. 2—Aug. 31
Rare plot	Jul. 1—Jul. 19	Jul. 20—Jul. 31	Aug. 1—Aug. 31

In a study of the vertical temperature cross-sections of the rice plots (I. BÁRÁNY—J. BOROS 1972), it was found that in the various phases of plant development the temperature varies most significantly in the panicle level, and proceeding downwards from this the change of temperature is less in the periods of the development of the stems, and the development of the panicles and flowering.

The difference and phase shifts of the duration of the hot stage characteristic of the irradiation period and the cold stage characteristic of the radiation period can be seen from the relative temperature data expressed as percentages of the maxima obtained from the hourly mean values of the phenophases (Tables 1 and 2).

TABLE 1

Hourly relative temperature (in %) in a rice plot copiously treated with artificial fertilizer

Hour	Tillering					Development of stems					Development of panicles—flowering—maturation				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	5	6	21	23	31	7	10	34	37	79	9	16	40	50	79
2	2	3	17	19	25	8	9	29	32	73	5	11	34	43	73
3	1	0	11	13	17	5	7	23	21	62	2	5	29	36	62
4	0	0	7	7	12	0	0	19	22	52	0	1	23	29	52
5	5	2	3	3	6	3	0	15	18	41	2	0	17	23	41
6	19	15	0	0	0	12	8	9	12	31	16	8	12	18	31
7	39	29	3	1	0	20	15	5	3	21	39	18	8	13	21
8	50	45	6	3	2	47	21	0	0	7	61	29	2	2	7
9	72	61	22	16	8	63	32	0	0	0	72	38	0	0	0
10	80	72	41	35	21	77	39	8	4	3	78	55	12	9	3
11	88	83	60	55	38	84	65	29	19	14	89	73	29	23	14
12	95	95	83	74	58	95	87	53	46	28	95	90	52	39	28
13	97	96	93	90	75	99	99	77	68	41	100	100	73	59	41
14	100	100	98	98	86	100	100	95	88	55	96	99	88	77	55
15	94	93	100	100	96	92	93	100	100	76	95	94	98	91	76
16	88	86	95	98	100	92	91	100	99	76	88	83	100	98	76
17	78	77	88	90	96	84	85	97	99	86	78	80	98	100	86
18	63	64	79	83	92	70	74	92	99	93	57	60	92	100	93
19	45	60	77	71	87	48	62	83	91	97	38	55	82	95	97
20	31	35	58	61	77	35	48	80	84	100	28	59	71	88	100
21	21	27	49	52	67	30	41	73	75	69	23	50	65	77	69
22	18	21	41	45	58	26	34	61	66	66	19	44	58	68	66
23	12	14	34	36	46	17	30	53	57	59	14	38	50	61	59
24	10	11	27	20	38	16	22	46	51	52	11	31	44	52	52

A = panicle level B = 10 cm above water C = 1 cm below water level D = middle of water
E = bottom of water

That part of the heating-up stage with a relative temperature of 70—100% in the various phenophases is delayed by 1—2 hours in both plots.

The difference between the air and water temperatures in both plots can clearly be discerned on the basis of the relative temperature. The difference in diurnal heating-up between the two plots is still small at the time of tillering. On the development of the stems in the dense plot the hot stage 10 cm above the water begins 1 hour later than in the panicle level, and lasts an hour longer.

With the thickening of the vegetative parts of the plant the shading effect increases, and this produces a change in the heating-up conditions of the 10 cm air layer and the water below it.

At the time of the development of the panicles and the flowering the temperature values reaching and exceeding 70% in the various levels from above downwards occur with a difference of 2 hours (a 1-hour difference can be observed only between the water level and the middle of the water).

TABLE 2

Hourly relative temperature (in %) in a control rice plot treated with artificial fertilizer

Hour	Tillering					Development of stems					Development of panicles—flowering—maturation				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	10	10	18	18	21	6	7	23	23	29	10	10	30	36	58
2	5	5	9	12	14	5	7	20	18	23	6	6	24	29	47
3	2	3	7	7	9	3	5	14	12	16	3	3	18	24	37
4	0	0	2	3	4	0	1	9	7	11	0	0	13	18	29
5	9	8	0	0	0	2	0	5	3	4	2	1	8	13	21
6	26	21	2	0	0	17	8	0	0	0	18	9	3	7	13
7	45	40	9	6	5	35	26	3	0	0	43	26	2	4	8
8	60	55	19	15	13	50	40	5	1	0	61	48	0	0	0
9	72	69	47	22	26	60	53	10	7	0	70	65	8	5	3
10	79	75	53	39	43	70	65	23	20	7	78	75	27	24	18
11	87	81	69	69	60	78	73	41	38	20	87	84	50	44	37
12	91	90	84	83	77	89	88	65	61	39	94	94	73	63	58
13	96	98	95	95	92	95	98	84	81	61	99	100	87	80	74
14	99	100	100	100	100	100	100	97	97	80	100	100	98	92	84
15	100	100	98	99	100	99	98	100	100	91	99	97	100	98	92
16	96	97	91	92	96	98	92	99	100	95	92	87	98	100	97
17	88	87	82	83	89	93	74	93	96	100	83	74	90	96	100
18	76	74	73	73	80	76	54	87	89	97	65	55	81	89	100
19	54	52	63	62	71	51	41	79	74	93	40	39	71	82	97
20	36	36	52	51	59	39	38	72	71	86	31	32	63	72	95
21	26	25	44	42	50	34	30	62	63	79	24	25	55	64	90
22	20	21	35	35	42	17	24	55	55	70	20	20	47	56	79
23	15	15	27	27	33	22	24	45	47	61	16	16	40	49	70
24	11	12	21	21	25	18	20	40	40	52	11	12	27	40	60

A = panicle level B = 10 cm above water C = 1 cm below water level D = middle of water E = bottom of water

Similarly to what was observed at the time of development of the stems, at the bottom of the water there are high relative temperature values for a longer time prior to the maximum, and then immediately after the maximum the intense cooling down begins.

It is striking that the water begins to cool down with a 4—5, and sometimes even 6-hour delay compared to the air temperature. This delay increases with the progress of the phenophases.

Based on the courses of the relative temperatures, the developmental process of the plot climate occurs decisively at the time of development of the panicles and flowering.

From the isochrones of the maxima and minima (Figure 1 and 2) it can be stated that the minima occur later in the dense plot than in the rare plot. this being the more so in the dense plot than in the rare plot.
The times of the maxima and minima at the various levels are best differentiated at the time of development of the panicles and the flowering. At the panicle level and at 10 cm the minima occur earlier in this

period than at the time of development of the stems; this can be explained by the change of habit of the plant.

Proceeding downwards from the surface of the water, a delay of about 20 minutes can be observed in both plots. The isochrones of the maxima clearly show the differences in the plot. At the time of tillering

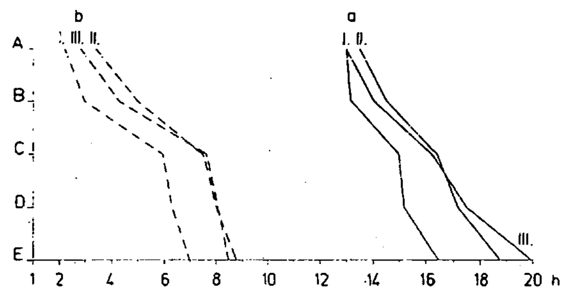

Figure 1. Isochrones of the extreme temperature values in the dense rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = maxima; b = minima.
A = panicle level; B = 10 cm; C = 1 cm below water level; D = middle of water; E = bottom of water.

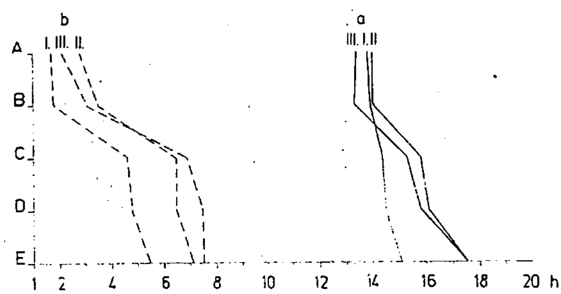

Figure 2. Isochrones of the extreme temperature values in the rare rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = maxima; b = minima.
A = panicle level; B = 10 cm; C = 1 cm below water level; D = middle of water; E = bottom of water.

in the rare plot, where direct radiation can penetrate into the plot without obstacle, the maxima are established in all the levels one after another within half an hour, whereas in the dense plot a period of 3 hours is necessary for this.

At the time of the development of the stems in the panicle level the maximum appears earlier in the dense plot than in the rare plot. From 10 cm downwards, however, the maximum can be observed earlier in the rarer plot. Similarly to the minima, the occurrence of the maxima is most extended at the time of development of the panicles and the flowering, this being the more so in the dense plot than in the rare plot.

Besides the times of appearance of the extreme temperature values, the differences of the values of the maxima and minima also develop in accordance with the plot climate (Tables 3 and 4). Only the maximum temperature was measured at the climate station, and the time of its occurrence was not recorded.

TABLE 3
Heavily fertilized rice plot

	Max. °C	Time hours	Min. °C	Time hours
		Tillering (Jul. 1—Jul. 21)		
A	25,7	$13^h\,00^m$	14,0	$2^h\,12^m$
B	24,8	$13^h\,12^m$	15,2	$3^h\,00^m$
C	25,0	$15^h\,00^m$	17,6	$6^h\,00^m$
D	24,8	$15^h\,12^m$	17,7	$6^h\,18^m$
E	23,0	$16^h\,30^m$	17,6	$7^h\,00^m$
F	24,8	—	14,3	—
		Development of stems (Jul. 22—Aug. 1)		
A	27,1	$13^h\,30^m$	15,5	$3^h\,24^m$
B	25,3	$14^h\,30^m$	17,0	$5^h\,00^m$
C	26,1	$16^h\,24^m$	18,3	$7^h\,30^m$
D	25,5	$17^h\,12^m$	18,2	$8^h\,00^m$
E	23,3	$18^h\,48^m$	17,8	$8^h\,48^m$
F	27,8	—	16,9	—
		Development of panicles and flowering (Aug. 2—Aug. 31)		
A	28,4	$13^h\,00^m$	15,1	$2^h\,48^m$
B	24,3	$14^h\,00^m$	17,1	$4^h\,18^m$
C	24,1	$16^h\,12^m$	18,8	$7^h\,36^m$
D	23,3	$17^h\,30^m$	18,9	$8^h\,06^m$
E	21,0	$20^h\,00^m$	18,3	$8^h\,30^m$
F	27,6	—	15,4	—

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water E = bottom of water F = clime station

At the time of tillering in the two plots the phenophase centres of the maxima do not yet differ significantly. On the development of the stems the difference between the panicle level and 10 cm maxima increases, and at the time of development of the panicles and the flowering the difference is definite. During the development of the plant from 10 cm the activity level is gradually transferred to the panicle level. In accordance with this, at the time of development of the panicles and flowering the maximum is the highest at the panicle level in both plots. At 10 cm

TABLE 4

Unfertilized rice plot

	Max. °C	Time hours	Min. °C	Time hours
		Tillering (Jul. 8—Jul. 19)		
A	26,1	$13^h\,48^m$	14,8	$1^h\,42^m$
B	26,3	$13^h\,54^m$	15,0	$1^h\,48^m$
C	26,8	$14^h\,24^m$	17,8	$4^h\,36^m$
D	27,1	$14^h\,30^m$	17,9	$4^h\,48^m$
E	25,8	$15^h\,06^m$	18,0	$5^h\,30^m$
F	25,2	—	14,4	—
		Development of stems (Jul. 20—Jul. 31)		
A	26,4	$14^h\,00^m$	15,0	$2^h\,48^m$
B	26,5	$14^h\,00^m$	15,7	$3^h\,30^m$
C	26,0	$15^h\,48^m$	18,1	$6^h\,30^m$
D	25,9	$16^h\,06^m$	18,0	$6^h\,30^m$
E	24,0	$17^h\,30^m$	18,2	$7^h\,06^m$
F	26,5	—	16,1	—
		Development of panicles and flowering (Aug. 1—Aug. 31)		
A	28,5	$13^h\,24^m$	15,7	$2^h\,06^m$
B	28,4	$13^h\,18^m$	16,5	$3^h\,06^m$
C	25,7	$15^h\,18^m$	19,3	$6^h\,54^m$
D	25,0	$15^h\,48^m$	19,4	$7^h\,30^m$
E	23,0	$17^h\,30^m$	19,2	$7^h\,30^m$
F	27,6	—	15,5	—

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water E = bottom of water F = clime station

and in the water the maxima are delayed and are lower. In all three phenophases the minima are lowest in the panicle level corresponding to the activity level.

The characteristics of the courses of the temperatures of the dense and rare plots, and within them of the different levels, are presented by means of the trigonometrical polynomials of the course of the average daily temperature in the various phenophases.

Similarly to other meteorological elements of continuous distribution, the compensated temperature courses can be depicted for all the phenophases from the characteristic data of the 24 and 12-hour waves of the temperature course (Tables 5 and 6) on the basis of the following relation:

$$y = K + a \sin \frac{2\pi}{T} t + U$$

where K = mean temperature (°C),
a = amplitude (°C),
T = 24 or 12 hours,
t = the current time, and
U = phase angle (°).

In the knowledge of the amplitudes and phase angles, a comparison is made of the 24 and 12-hour waves of the temperature below the water level and the 10 cm air temperature which well reflect the effects of the plot (Figures 3 and 4).

TABLE 5

Characteristic values of the trigonometrical polynomials in the heavily fertilized rice plot

		A			B			C			D			E		
		K	a	U	K	a	U	K	a	U	K	a	U	K	a	U
I.	$\frac{2\pi}{24}$	19,3	5,6	249	19,5	4,7	240	21,0	3,3	211	20,9	3,2	205	20,1	2,6	187
	$\frac{2\pi}{12}$		0,6	90		0,6	84		0,8	30		0,8	30		0,5	0
II.	$\frac{2\pi}{24}$	20,7	5,5	240	20,7	3,9	222	22,0	3,4	183	21,7	3,2	180	20,5	2,5	154
	$\frac{2\pi}{12}$		0,9	69		0,8	45		1,0	12		1,0	8		0,5	57
III.	$\frac{2\pi}{24}$	20,8	6,4	249	20,3	3,3	229	21,3	2,3	183	21,0	1,9	172	19,8	1,2	135
	$\frac{2\pi}{12}$		1,0	87		0,7	63		0,8	9		0,5	27		0,2	15

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water
E = bottom of water K = mean temperature (°C) a = amplitude (°C)
U = phase angle (°) I = tillering II = development of stems III = development of panicles-flowering

The difference of the amplitudes between the 10 cm and the water level in the case of the 24-hour wave was the greatest in the panicle development — flowering stage in the dense plot. In no phase, however, does the difference exceed 2 °C. In contrast, in the rare plot this difference is more than 3 °C in all three phenophases. The greatest is 5.8 °C at the time of panicle development — flowering. In accordance with this, the phase delay in the appearance of the maxima also increases here.

TABLE 6

Characteristic values of the trigonometrical polynomials in the unfertilized rice plot

		A			B			C			D			E		
		K	a	U	K	a	U	K	a	U	K	a	U	K	a	U
I.	$\frac{2\pi}{24}$	20,2	5,6	253	20,2	6,1	241	21,9	4,2	222	22,0	4,2	220	21,5	3,6	213
	$\frac{2\pi}{12}$		0,3	60		0,4	45		0,8	60		1,0	51		0,8	36
II.	$\frac{2\pi}{24}$	20,3	5,5	237	20,5	5,3	229	21,8	3,6	195	21,8	3,6	192	20,9	2,8	176
	$\frac{2\pi}{12}$		0,5	45		0,8	51		0,8	15		0,8	15		0,3	45
III.	$\frac{2\pi}{24}$	21,3	6,3	245	21,6	5,7	253	22,2	2,8	199	22,0	2,5	187	21,2	1,8	172
	$\frac{2\pi}{12}$		0,7	75		1,2	69		0,9	18		0,7	9		0,3	6

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water E = bottom of water
K = mean temperature (°C) a = amplitude (°C) U = phase angle (°)
I = tillering II = development of stems III = development of panicles — flowering

There is no substantial difference between the amplitudes of the 12-hour waves, but the delay is greater in the rare than in the dense plot.

From examination of the relative and extreme temperature values it can be stated that the features of the plot climate are convincingly reflected by the difference between the heating-up of the 10 cm and the panicle level with the transfer of the active surface to the panicle level in the irradiation stage.

It may be said that as a result of the heavy fertilization the vegetative parts of the plant begin to develop rapidly, and because of the large mass of leaves the active level is found in the panicle level (the most closed part of the leaf zone) both by day and by night; as a consequence of this the diurnal course of the temperature will be the most extreme here, while the temperature course is more balanced in the levels below the closed leaf zone and in the water.

The temperature of the rare control plot, however, resembles that of the free water surface, as regards both the daily courses, and the sizes and the times of occurrence of the extreme values.

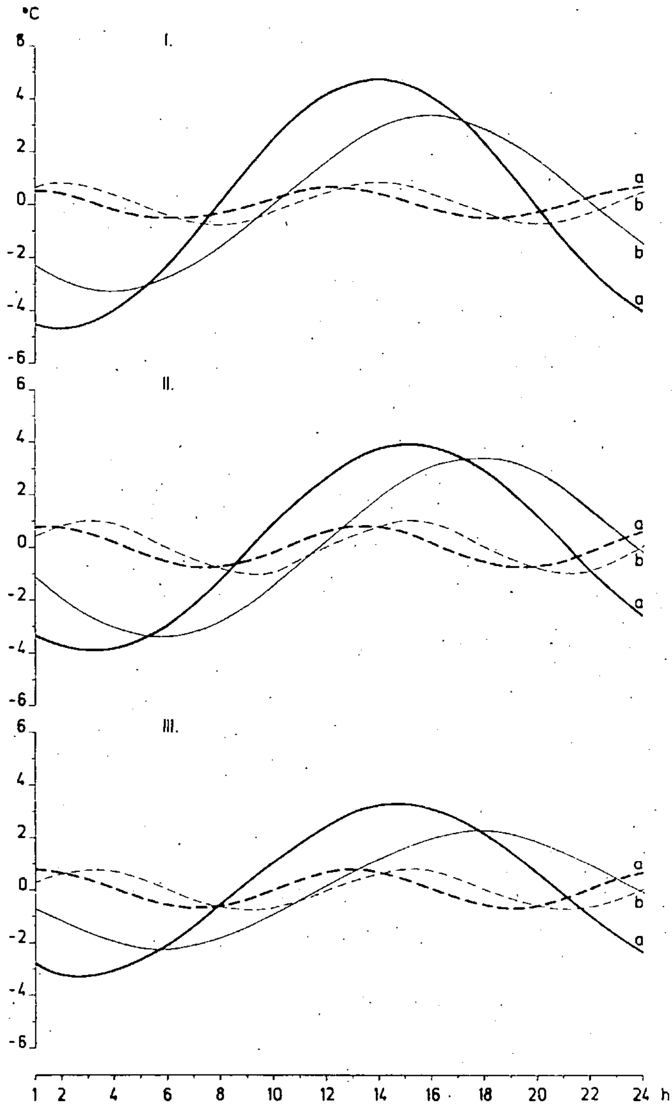

Figure 3. 24 an 12-hour waves of the trigonometrical polynomials in the dense rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = 10 cm; b = 1 cm below water level.

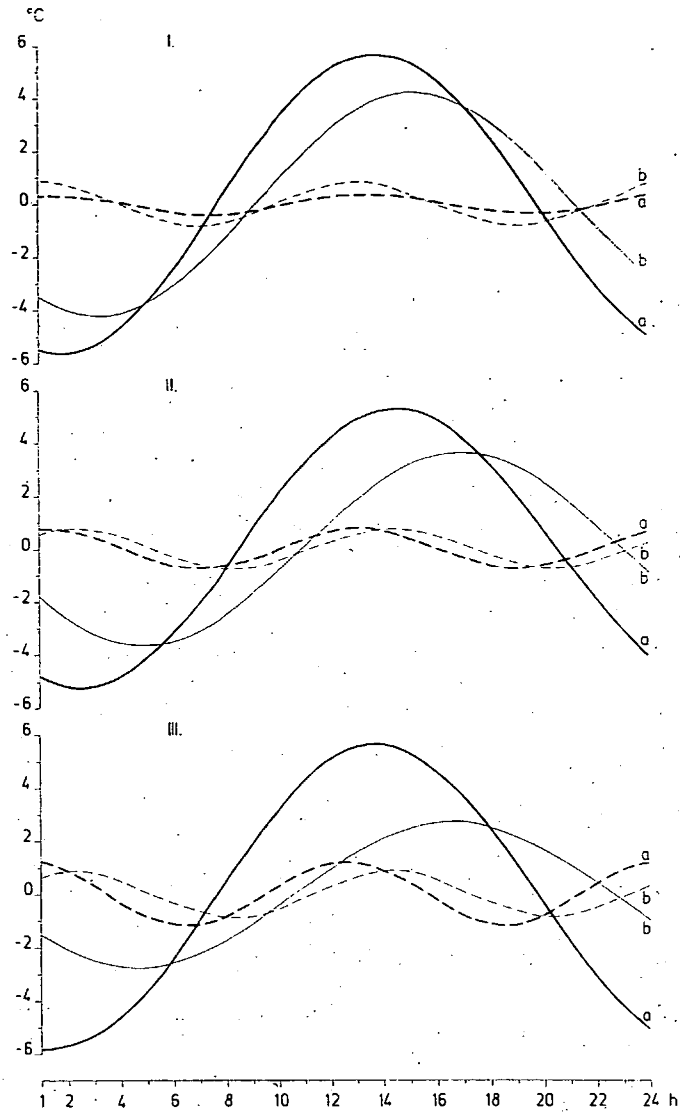

Figure 4. 24 and 12-hour waves of the trigonometrical polynomials in the rare rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = 10 cm; b = 1 cm below water level.

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