Data Concerning the Soil Temperature Conditions of Rice Stand with Flooding Water Cover of Different Depths

by

J. Juhász — Cs. Károssy and Á. Kiss

Adatok különböző magasságú árasztóvízzel művelt rizsállomány talajhőmérsékleti viszonyaihoz. A hazai rizstermesztés terméseredményei a rizs klímaigényessége és betegségekre való fogékonysága következtében nagyon változóak. A különböző okok folytán fellépő termésvisszaesések megfelelő agrotechnikai módszerek alkalmazásával elkerülhetők lehetnek, ha a klímatényezők és a rizsnövény fejlődése közötti szoros összefüggés természetét és mennyiségi vonatkozásait megismerjük.

Kutatási területünk szerves része a Dél-Alföld természeti tájainak. Tanulmányunkban rövid talajtani jellemzést adunk Szarvas környékének talajairól; kitérünk továbbá a felszínt alkotó talajrétegek fizikai és kémiai sajátságainak ismertetésére is.

A genetikus talajtípusok fejlődését kis területegységeken mutatjuk be, mivel a részletek közötti összefüggések csak kis területegységeken belül mutathatók ki. A Dél-Alföld természeti tájainak földrajzi osztályozásánál különös figyelemmel vagyunk a Körös-vidék és a Dél-Tisztántúl löszfennsíkjának talajviszonyaira.

A rizs fejlődéséhez nagyon fontos az optimális, vagy közel optimális talajhőmérséklet. Az árasztóvízzel művelt rizsállomány talajhőmérséklete — az árasztóvíz jó hőszigetelő képessége és nagy hőkapacitása következtében — a növény jó fejlődéséhez szükséges optimum közelében van. A különböző magasságú árasztóvízzel borított, különböző mélységű talajrétegek hőmérsékletének napi ingása júniustól szeptemberig különböző mértékben csökken.

Ez a csökkenés összefügg a növényállomány növekedésével és zártabbá válásával. Az összefüggő bugaszint fejlődésével a fényenergia egy része a bugaszintben használódik fel és így kevesebb energia éri a vízfelszínt és a talajfelszínt. Szeptember elején az árasztóvíz leeresztése után a bugaszinten átjutó besugárzás közvetlenül a talajfelszínt éri és a talaj felső szintje közvetlenül érintkezik a levegővel. Ennek következtében a száradó talajban a hőmérséklet napi amplitudója növekszik. Az árasztóvíz leeresztése után a talaj nedvességtartalmában és hőmérsékletében beálló változások elősegítik a növény teljes kifejlődését és a magvak érését.

Angaben zu den Bodentemperaturverhältnissen des Reisbestandes unter verschieden tiefer Wasserbedeckung. Die Ertragsdurchschnitte des heimatlichen Reisbaus sind sehr veränderlich wegen der Klimaanspruchsvollheit und Krankheitsempfindlichkeit des Reises. Die aus verschiedenen Ursachen erfolgenden Ertragsrückfälle können mit geeigneten agrotechnischen Methoden vermieden werden, wenn die Art und das Mass des engen Zusammenhangs zwischen gegebenen Klimaeinflüssen und der Entwicklung des Reises uns bekannt sind.

Das untersuchte Gebiet ist ein organischer Teil der Naturlandschaft der südlichen ungarischen Tiefebene. In einer kurzen Bewertung in der Abhandlung wird eine bodenkundige Klassifizierung der Gegend von Szarvas gegeben; daneben werden die physischen und chemischen Eigenschaften der die Oberfläche bildenben Bodenschichten beschrieben.

Die Entwicklung der genetischen Bodentypen werden in kleineren Gebietseinheiten angegeben, weil die Zusammenhänge der Einzelheiten nur innerhalb der kleinen Einheiten nachweisbar sind. Bei der geographischen Naturlandschaftseinteilung der südlichen Grossebene wird besondere Aufmerksamkeit den Bodenverhältnissen der Körös—Gebiet und der Lössebene des südlichen Tiszántúl (der Ebene östlich von der Theiss) gegeben.

Zur guten Entwicklung des Reises ist die Versicherung optimaler oder beinahe optimaler Bodentemperatur sehr wichtig. Die Bodentemperatur des mit Überschwemmungswasser kultivierten Reisbestandes ist — infolge der guten Wärmeisolierung und der grossen Wärmekapazität der Was

sermenge — in der Nähe des zum guten Wachstum der Pflanze nötigen Optimums. Die Tagesschwankung der Temperatur verschieden tiefer Bodenschichten unter verschieden tiefer Wasserbedeckung vermindert sich, in verschiedenem Masse, von Juni bis September.

Diese Verminderung hängt mit dem Wachstum und Geschlossenerwerden des Pflanzenbestandes zusammen. Mit der Entwicklung der zusammenhängenden Rispenzone wird ein grosser Teil der zum Reifen der Körner nötigen Lichtenergie in der Rispenzone benutzt und dadurch erreicht viel weniger Energie die Wasser- und die Bodenoberfläche. Anfang September nach dem Ablassen des Überschwemmungswassers erreicht die durch die Rispenzone durchdringende Einstrahlung den Boden unmittelbar, und die obere Schicht des Bodens kommt in direkte Berührung mit der Luft. Infolgedessen nimmt die Amplitude des Tagesganges der Temperatur im trocknenden Boden wieder zu. Nach dem Ablassen des Überschwemmungswassers begünstigen die Effekte der Veränderungen des Feuchtigkeitsinhalts der Temperatur des Bodens die volle Entwicklung der Pflanze und das Reifen der Körner.

The average rice crop yields in this country are very variable owing to the particular demands and susceptibility to disease of rice. Crop failures due to different causes can be avoided by suitable agrotechnical methods if we know the nature and extent of the relationship between the development of rice and the climatic conditions connected with the way of raising the crops.

The investigated area is an organic part of the natural landscape of the Southern Lowland. In a short analysis the pedological classification and the physical and chemical properties of the soil layers forming the surface in the region of Szarvas are described.

The development of the genetic soil types is described for smaller area units, because the connections between the parts can be demonstrated only within small units. In classifying the natural landscape of the Southern Lowland we are chiefly concerned, according to the purpose of our investigation, with analyzing the soil conditions of the Körös region and the loess table of the southern Trans—Tisza region.

For suitable growth of rice it is essential to ensure optimal or near-optimal soil temperatures. The soil temperature of the flooded rice field — owing to the good heat insulation and great heat capacity of the water mass — is about the optimum required for the development of the plant.

The diurnial fluctuation of the temperature of soil layers with different water covers and different depths decreases, in varying degrees, from June to September. This decrease is connected with the development and closing of the plant stand. With the formation of the panicle zone a large part of the light energy needed for the ripening of the grains is absorbed and utilized in the panicle zone, and thus less energy reaches the surface of the water or the soil. At the beginning of September, after the flooding water drained, the radiation penetrating through the panicle zone reaches the soil directly, and the surface of the soil is also in direct contact with the air. As a result of all this the amplitude of the diurnial variation of the temperature begins to grow again in the drying soil. After draining the flooding water, the effects of the changes in the moisture content and the temperature of the soil favour the full development of the plant and the ripening of the grains.

The region under examination is an organic unit within the natural land of the Southern Lowland of Hungary. After a short analysis a pedological classification of the region of Szarvas is presented together with the physical and chemical properties of the material of soil lyers of the surface.

The formation of the genetic soil types is best described according to smaller territorial units because the connections between the parts and details can be shown only within such smaller units. In this respect we are in a fortunate position since a detailed description of the soil-geographical conditions is to be found in the work of Stefanovits on "The soils of Hungary" [1].

In building up the regional natural geographic classification of the Hungarian Southern Lowland, our main objective is — in accordance with the aim of our investigations — to give an analysis of the soil conditions of the loessial table of the Körös region and thet of the southern region east of the river Tisza.

The region of the river Körös

The affluents of the river Tisza often changed their bedsand so their network covers a great part of thet area. In the lowland, a continually sinking region, river control has left several reedy and swampy territories in the old river bede. The areas freed from the water slowly dried out, the groundwater level sank down and thus it could not very much influence the formation of the soils of this land. Almost one half of the meadow clay soil of Hungary is to be found in this region. The subsoil of the petchblack clayey territories is often alkaline, it contains sodium and magnesium. According to Máté [2] the humus layer of the soil is of minimal thickness, the proportion between clay and humus is inverse.

Opinions differas to the formation of meadow clay. The development of meadow sols is attributed abundant moisture (*Sigmond*) acidity of theclay deposited by the rivers (*Csiky*), the effect of water (*Endrédy*) and to the marshy soil (*Ballenegger*). In many cases however, meadow soils formed also on loessial ground [3]: such a region is the loess table of the southern region east of the Tisza. Meadow soils are also found on acid alluvial soils. But let us accept any one of the theories, in every one of them water is of decisive importance in the formation of meadow soils and clays.

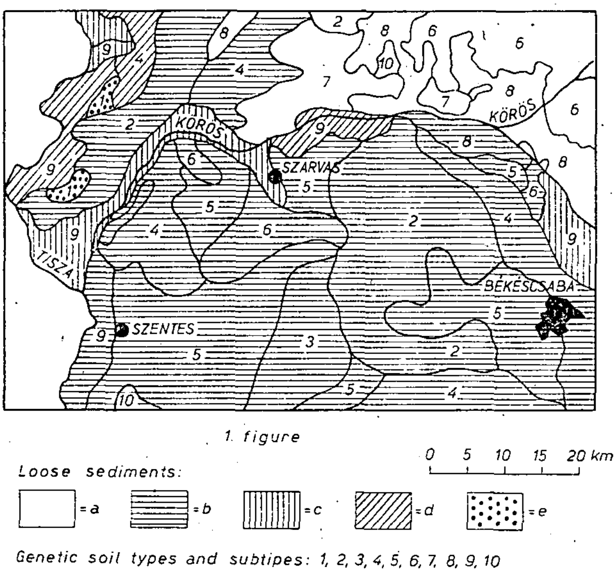

Fig. 1. Genetic soil map of Szarvas and its region according to Pál Stefanovits and László Szűcs

Symbols:

a = clay and clayey loam, loessial sediments; b = meadium compact clay, loessial sediments; c = clay and clayey loam, glacial and lacusstrine or alluvial sediments; d = medium compact loam, glacial and lacustrine or alluvial sediments; e = sandy glacial lacustrine sediments.

Genetic soil types and subtypes

1 = drift sand; 2 = lime-covered lowland chernozem; 3 = lime-covered lowland chernozem, alkaline in deep layers; 4 = meadow chernozem; 5 = meadow chernozem, alkaline in deep layers; 6 = steppifying meadow soloñetz; 7 = solonetz meadow soil; 8 = meadow soil; 9 = flood-deposit meadow soil; 10 = meadow solonetz

Table 1

(After Ibolya Kiss)
Values found in solonetz meadow soil at Galambos, 1965
a) The mechanical composition of solonetz meadow soil in %

Depth, cm	*Grain size, mm*						*Loss by treatment with hydrochloric acid*	*sand*	*clay*
	1,00—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	0,001			
0— 20	0,08	6,54	28,23	10,30	14,37	36,34	4,14	34,85	61,01
20— 40	0,83	1,96	23,75	14,13	8,20	47,14	3,99	26,54	69,47
40— 60	0,15	3,27	21,59	8,58	10,70	46,12	9,59	25,01	65,40
60— 80	0,07	0,98	25,68	9,09	11,86	45,25	7,08	26,73	66,20
80—100	0,09	2,76	32,42	12,20	6,95	37,36	8,11	35,27	56,51
100—120	0,20	9,24	37,13	6,15	10,49	30,83	5,96	46,57	47,47
120—140	0,14	14,48	33,62	9,11	7,79	29,25	5,61	48,24	46,15

Besides meadow soils, alkali soils of the solonetz type and their calciferous — sodic varieties the solontchak solonetzes play an important role (*Table 1*). Their amelioration was done by spreading yellow soil, limestone dust and caustic line [4]. The tempo and extent of the melioration is to be accelerated because the water amount of the existing irrigation canals is utilisable only after the melioration of the sodic soils.

The sodic and meadow soils of that land ara in some places characterized by a process of steppifying. The preliminary condition of that process is the change of water economy in the different soils, and a consequence of that is a quantitative and qualitative change in the fertile humus layer. Airlessness in the soil disappears, the acidity of the meadow soil decreases and thus an improvement, from the economical aspect, take splace.

The soils in the northern and eastern parts of this area show more favourable characteristics: meadow chernozem, salty meadow chernozem and chernozem with chalky sediment have developed (*Fig 1*).

The loess table of the Southern Trans-Tisza region — being a border-land — is of subdominant character since the region of Szarvas cannot be separated from this land.

The region is bordered by the rivers Körös, Tisza and Maros. The loessiel table extends also beyand the Rumanian border. In the formation of that land a great part was played by the river Maros which used to flow in other regions. Before the formation of the present river bed three periods may be distinguished [5]: other authors [6] make a distinction between several periods of stream deposit, silt transportation and periods of filling up, silting.

The Maros flows- with different periodical characteristich in a NW direction, then SW laying down its deposits. Reference to filling um in this region was already made by *Miháltz* (in connection with sedimentation). In connection with the filling-upprocess a series of deposits formed gaining in refinement from below urward. In some cases this deposit series became repeated. These deposits were modified also by climatological changes and thus the accumulated layers became covered by layers of sand, mud and clay.

Table 1

(After Ibolya Kiss)
Values found in solonetz meadow soil at Galambos, 1965
b) Basic data of meadow soil and analysis of its 1:5 watery extract

Mark of genetic depth, cm		Total salt	Phenol-phtalein alkalinity as soda	$CaCO_3$	Humus	pH	Watery solution (1:5)							
		%					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Co_3^{2-}	HCO_3^{-}	C^{-}	SO_4^{2-}
							mg eq/100 g							
A_{level}	0— 18	0,07	—	1,07	2,78	7,2	0,62	0,50	1,20	0,05	0,40	1,50	0,30	0,48
B_1	18— 46	0,17	—	—	1,57	7,5	0,14	0,40	3,94	0,07	0,40	1,90	0,81	0,67
B_2	46— 68	0,15	—	—	1,24	7,4	0,14	0,13	4,00	0,09	—	2,70	0,51	0,73
B_3	68—100	0,15	0,08	9,61	0,95	7,6	0,27	0,43	1,52	0,03	0,40	1,85	0,14	0,23
BC	100—130	0,16	0,06	14,50	0,46	7,7	0,10	0,20	4,56	0,11	0,60	3,10	0,31	0,77
C_1	130—180	0,19	0,05	8,50	—	7,9	0,10	0,92	4,90	0,19	0,80	2,75	0,41	1,35
C_2	180—210	0,23	0,02	5,34	—	7,6	0,22	0,67	6,12	0,07	0,40	1,90	0,46	4,05
							mg eq/litre							
Ground water						7,9	1,32	7,92	35,93*		0,10	12,50	0,56	32,01

* Calculated value

Table 1

(After Ibolya Kiss)
Values found in solonetz meadow soil in Galambos, 1965
c) Exchangeable cations of solonetz meadow soil

Mark of genetic level, depth, cm		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Weight	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
		mg eq/100 g					percentage of the weight			
A_{level}	0—18	25,70	7,00	1,09	0,46	34,25	75,04	20,44	3,18	1,34
B_1	18—46	13,50	17,70	5,87	0,56	37,63	35,87	47,04	15,60	1,49
B_2	46—68	9,30	15,40	7,87	0,46	33,03	28,15	46,62	23,82	1,40

d) Hrygroscopicalness, volume weight and compactness of solonetz meadow soil

		Hygroscopicalness	Volume weight	Compactness
A_{level}	0—30	5,05	1,49	56

Summarizing what has been said: the lowland lime-deposit chernozem can be found in the loess table of the southern Trans-Tisza region in a NE-SW direction connected with meadow chernozem and salty meadow chernozem and in the deeper regions meadow solonetz and steppifying meadow solonetz.

The utilization of the soils of that land is determined by the salt content, and the way of soil cultivation is to be made dependent on the distribution of salt in the different depths. Nevertheless the climatic and soil conditions are favourable even for the growth of more "demanding" plants. Melioration is motivated first of all in the meadow solonetzes and steppifying meadow solonetz soils.

Characterization of the material of the surface layers

The graine of river sand are sharp and angular while those of wind deposits rather round. The two kinds of sand can be separated according to their percentual composition [7]. The determination of the origin of some sandy layers can be made by the sedimented mud. The presence of mud alw fluvial origin, while there is no mud in windborn sand. Its other characteristic feature is the appearance of gasteropods, since in windborn sank pméy cpmtomemtaé sőecoes pr still-water species can be found. The water permeability of wind deposit sand is $k=10^{-3}$ cm/sec while that of river water is $k=10^{-2}$ cm/sec. The difference comes from the difference in composition. In the present case the characterization of the different kinds of loess is omitted: only a rough characterization of tide land loess and alkali-clayey loess is presented.

Tide land loess developed in the flood basins of rivers raising the clay-mud content of the area, because after the recession of the flood a large amount of suspended material was left behind. Its water permeability is smaller — 10^{-7} cm/sec than that of the other loesses.

In flood areas without an outlet alkalic clayey loess developed with a high clay content. Its development is partly parallel with loess-formation, partly a consequence of the present period of alkalization 7. Their origin can be traced back to water transport.

The results of the borings of *Mihāltz* enable us to give a rough outline of the fluvial deposits of the Valley of the Tisza and the Trans-Tisza region. 10 According to these, in the Tisza Valley (at a depth of some metres) and in the Trans-Tisza region fluvial deposits can be found.

The fluvial sand the in Pleistocene and Holocene layers finies-grained and mediumgrained respectively, (0,1—0,4 mm ∅) with a water permeability of 10^{-4} cm/sec. The medium-grain layers are to be found below and the fine-grained ones above. The deposits of the rivers Körös and of Maros are characterised generally by medium-grained sand. Into the category of the loose sand-water sand belong the rough-grained, medium-grained and fine-grained sand. The differentiation of the diameters of grains entails categorization of the different kinds of sand and differentiation of the leakage factors according to value, thus i.e.:

The factor of rough sand (grain: 0,5 mm) is 10^{-2} cm/sec;
The factor of fine-grained sand 0,1 mm) is 10^{-5} cm/sec;
The factor of mud with grains of 0,02—0,002 mm is 10^{-7} cm/sec.

The leakage factor shows an almost direct proportion with the diameter of the grains. If the value of the leakage factor attains 10^{-8} cm/sec the sediment is sludge, clay, i.e. practically an impermeable layer. The leakage factor of the flood-mud of the investigated areas is not much smaller than that of clay: it is 10^{-7} cm/sec. Where the flood-mud covers grassy areas the leakage factor increases:

Among grain crops the role of rice is an important and particular one: it is a plant requiring warmth and a water-cover as it is of tropical origin. The rice grown in this country — under conditions very different from those of its place of origin — responds most sensitively to the extreme weather conditions characteristic of this country.

Thes problems of the growing and acclimatization of rice, the selection of the most resistant sorts, experimentation with a view to find the most appropriate agro-technical methods, and also the investigation of the connections between the stand-climate of the different sorts of rice and the climatic influences, are debated questions to this day.

Within the programme of complex investigation on rice breeding and cultivation, climatological investigations were carried out by us — joining with the oecological and physiological investigation carried out by the Research Institute for Irrigation in Szarvas — in 1975 at the experimental station of the above Institute in Galambos; the investigations were carried out in a rice stand covered with flooding water of various depths.

As is generally known, rice grown with flooding gives the best crop results in warm and dry years abundant in sunshine [8., 9., 10.].

Since the wather of the summer months of 1975 was far from that, it seems necessary to give a short characteristic of the weather of the above period 11.

The summer months of 1975 were unusually rainy and moderately cool. The precipitation amount of the months June, July and August surpassed in the greater part of the Hungarian Lowland 175% of the average of many years, and in the southern part of the region between the Danube and Tisza even 200% of the normal value. According to the data of the climatological station of Szarvas the precipitation amount of the summer months was 295 mm, i.e. 189% of 50 years' normal value. Correspondingly to the abundant precipitation the number of sunshine hours was very small; 704 hours of summer sunshine duration is 83% of the normal. Accordingly the summer amount of the short-wave global radiation was considerably less than the average radiation values: 47,42 cal cm^{-2}.

The mean temperature of the summer months was by 0,5—1 °C lower than 50 years' normal value. The moderately cool summer weather gave less balanced extreme temperature values. The average daily maximum temperatures remained below 33 °C (as against the normal 35—36 °C). The number of heat-days was only 10 during the whole summer period, while their usual number is 25 in Szarvas 12.

Within our research programme the temperature of the soil lying under the cover of flooding water of different depthes was registered with thermo-electric thermometers. The daily energy-amounts of short-wave global radiation were measured with a Kipp-type radiation-integrator and the daily values of the sunshine duration were recorded with a Campbell—Stokes sunshine recorder. On the basis of the collected data connections were sought between the depth of the flooding water and the soil temperature, and also between the sunshine duration and the short-wave global radiation.

As the first step of the investigations, the daily values of global radiation and sunshine duration, the factors primarily influencing the soil temperature, were compared month for month by drawing their regression curves (*Fig. 2*).

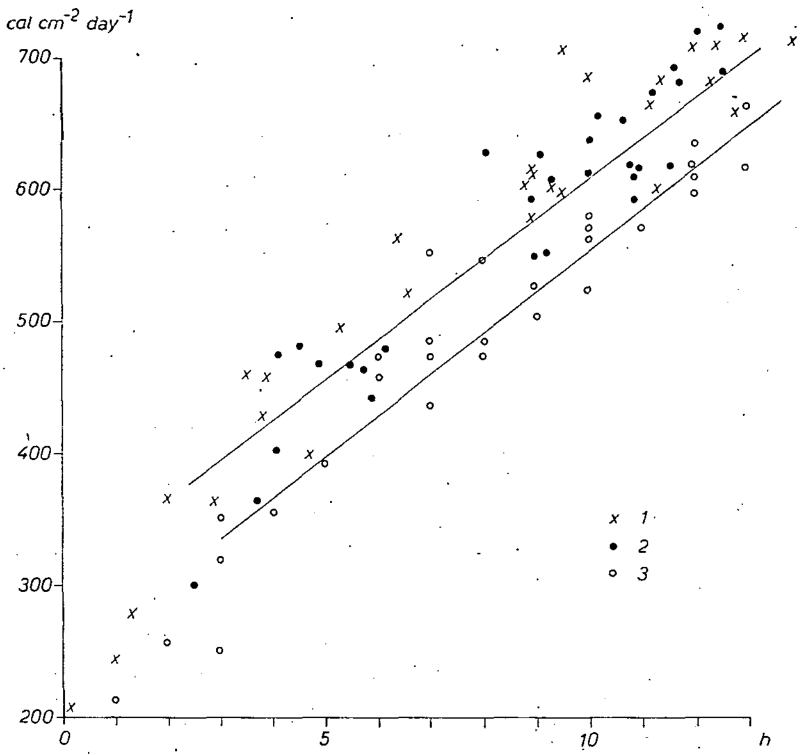

Fig. 2. Diurnal sums of global solar radiation and the empiric regression lines of the diurnal sums of sunshine at Szarvas, (June—July, 1975)
Key: 1=June, 2=July, 3=August

The points in the above *Fig. 2* show a marked scattering around the empirical regression curves show a positive correlation but in the smaller value-ranges an obviously curvilinear correlation was found. Neglecting the overcast days (with values of global radiation lower than 350 cal cm^{-2} day^{-1} [13], we found a regression line instead of the empirical regression curves. The empirical regression lines can be considered approximately identical in June and July, while in August it is a line almost parallel with the lines of the previous two months shifted towards the smaller calory-values. The considerable deviation of the regression lines can be explained with the lower values of the sun's altitude in August and with the radiationweakening effect of the oceanic air masses streaming in more frequently in August [14].

In the region studied here soil temperature was measured at three measuring places — in accordance with the depth of the flooding water. These depths were: "shallow water" (*S*): a water layer of 5—10 cm; "medium deep water" (*K*): 10—15 cm and "deep water" (*M*), a water layer of 20—25 cm. The thermoelectric thermometers were fixid at two layers each measuring point. The thermometers situated in the highest layer of the soil below the water ara designated with "*f*" (surface), those placed deeper in the soil with "*t*" (in the soil). Thus at the three measuring places the following measuring points can be distinguished: S_f, S_t, K_f, K_t, M_f and M_t.

The data containing the temperature trend of the soil covered by flooding water of different depths were analysed by hourly division and from the hourly temperature

Table 2

Monthly mean values of the temperature of the soil layers under flooding water of various depths Szarvas, June, July, August and September, 1975

		Mean			Maximum			Minimum			Amplitude		
VI.	surface-near soil	24,2	22,9	19,6	28,2	27,7	23,2	20,6	27,7	23,2	7,7	8,8	6,9
	deeper soil	20,3	23,0	20,9	21,7	26,9	24,7	15,3	19,7	17,2	6,4	7,2	7,2
VII.	surface near soil	23,8	22,9	21,8	25,5	24,8	24,3	22,0	20,9	20,7	3,5	3,9	3,6
	deeper soil	23,0	23,5	24,3	25,0	25,0	25,7	22,3	21,9	22,8	2,7	3,1	2,9
VIII.	surface-near soil	21,1	20,3	19,4	21,8	21,1	20,0	20,2	19,3	18,5	1,6	1,8	1,5
	deeper soil	22,0	21,2	21,4	22,6	21,8	21,9	21,4	20,4	20,9	1,2	1,6	1,0
IX.	surface-near soil	17,5	16,4	17,4	19,0	17,3	21,0	12,1	10,3	11,2	4,1	4,3	6,0
	deeper soil	18,9	17,7	19,5	18,1	22,8	14,1	14,1	12,1	14,1	3,1	3,7	4,8

values thus obtained daily and monthly mean values were calculated. We determined also the monthly average values of the maxima and minima of soil temperatures and also their monthly average amplitudes. *Table 2* contains the monthly mean values of the temperatures of the soil layers under flooding water of different depths.

From this *Table* it can be seen that in June, from among the monthly mean temperatures of the six measuring points S_f (upper soil layer of the shallow water cover) is the lowest: the difference is about 4,6 °C.

Similarly, a large temperature difference appeared at the measuring station S between two points of different depths (3,9 °C). At the other two measuring places and at measuring places covered by deeper flooding water only smaller differences were found between the monthly mean temperatures of the levels of different depths. In the soil layers covered with deeper flooding water the deeper soil layers are warmer by 0,1—1,3 °C. In July already the monthly mean temperature of M_t of the deeper soil layers of the "deep water" is the highest, while in the upper soil layer of the same measuring place the monthly average of M_f is the smallest among the monthly mean temperature values of the six measuring places. Their difference is 2,5 °C, i.e. by 1,4 °C smaller than the difference of the previous month. At the measuring place "shallow water" the upper soil layer is still warmer than the deeper layer: only by 0,8 °C (as against 3,9 °C of the previous month). In August the deeper layer is warmer at all the three measuring places: their difference is 0,9—2,0 °C in favour of the deeper soil layers.

Between the individual measuring pints the deeper soil layer is somewhat warmer. The smallest mean value can be found — like in the previous months too — at the point M_f.

The monthly average of the temperature of the upper soil layers decreases at the measuring place "shallow water" from June till September; it is of the same value at "medium deep water" in June and July, and than it decreases until September. At the measuring place "deep water" the mean value of soil temperature still increases from June to July, while from July to September it decreases. The monthly mean temperature value of the deeper soil layer is, at each of the three measuring places, higher in July than in June, while it decreases from July to September. According to the above, the monthly average of the soil temperatures is the highest in July at all measuring places with the exception of the measuring points S_f [15].

The decrease of the monthly average values of the soil temperatures (beginning from July) is obviously in connection with the decrease of global radiation, but here also the role of the development os the rice stand is to be analysed [16].

To that end the closeness of the connection between the daily temperature of the soil of the rice stand and the daily global radiation amount was analysed by the sid of regression and correlation computations (concerning the months July and August).

For the comparison the soil temperature of the upper layers of the soil of the measuring place "shallow water" (S_f) and that of the deeper layer of the soil of the measuring place "deep water" was chosen. By graphic procedure it was found that the connection can be considered linear.

The results of the computations were the following:

July

	Equation of the regression line	*Residual scattering*	*Correlation coefficient*
S_f	$y = 12{,}4\ °C + 0{,}024\,x$	2,0 °C	0.5178 ($n = 22$)
M_t	$y = 20{,}5\ °C + 0{,}0068\,x$	2,1 °C	0,3655 ($n = 22$)

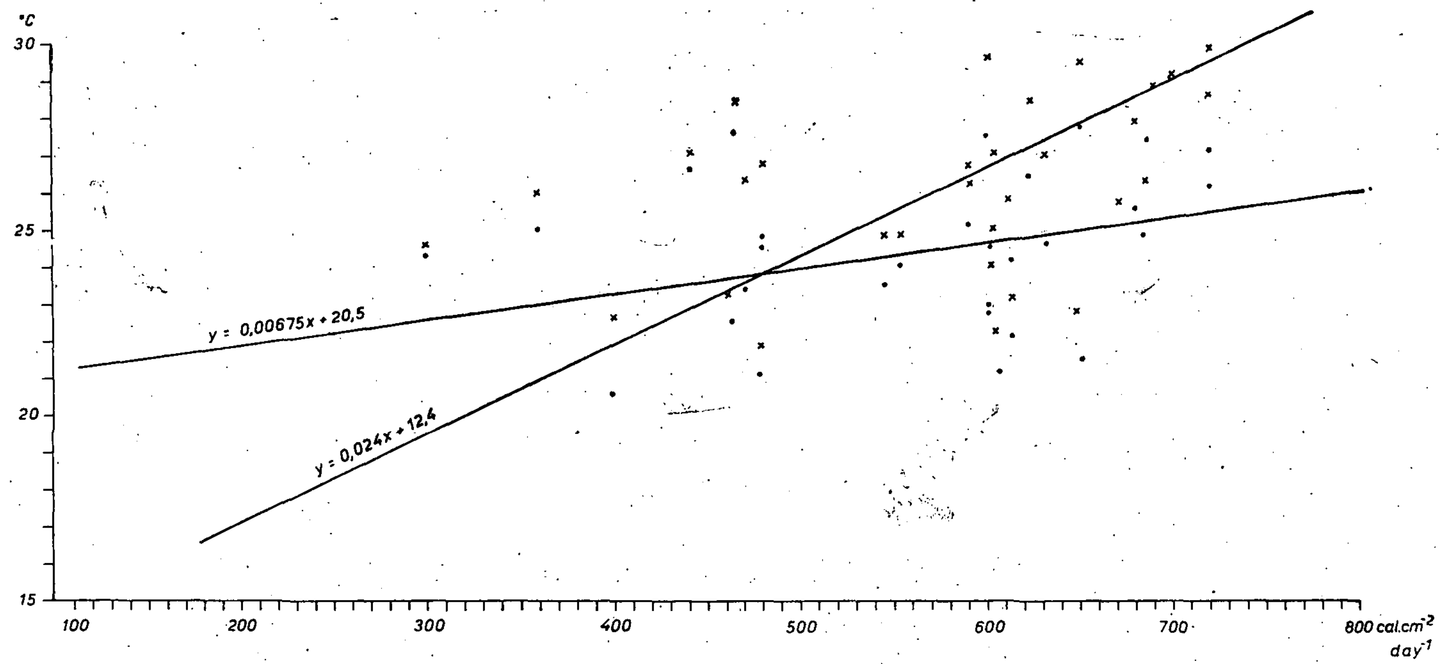

Fig. 3. Correlation of the diurnal mean temperature of the upper soil layer under „shallow water". and that of the deeper soil layer under deep water with the diurnal sum of global radiation in July. The S_f layer is the surface-near layer of the soil of „shallow water", the M_t layer is the deeper layer of the soil of „deep water". The values of the diurnal mean temperature of the S_f layer are marked by x, the layers of M_t by dots. The equation $y=0{,}024x+$ $+12{,}4°$ is the equation of the S_f layer, and the equation $y=0{,}00675x+20{,}5°$ is the equation of the regression line of the M_t layer ($x=cal\ cm^{-2}\ day^{-1}$).

August

S_f	$y = 20{,}0\,°C + 0{,}0025\,x$	0,9 °C	0,4150 ($n = 30$)
M_t	$y = 20{,}6\,°C + 0{,}0018\,x$	0,8 °C	0,3333 ($n = 30$)

y = the temperature of the individual layers of the soil,
x = the daily amount of global radiation in cal cm⁻².

From the above it can be stated that the daily mean temperature of the deeper soil of the measuring place "deep water" shows a weaker correlation with the daily amount of global radiation than the mean temperature of the layer S_f of the measuring place "shallow water", and the value of the regression coefficient too, is smaller than the regression coefficient of the soil of the deep water.

In August the correlation between the daily mean temperatures of the two measuring points and the global radiation is considerably smaller than in July and even the regression coefficients are much smaller. In the case of the soil near the surface below the shallow water the coefficient of the regression line decreased by the tenfold order of magnitude from July to August, and by more than a tenth the value of the correlation coefficient. The rest of scattering around the line also decreased to more than one half. In the case of the deeper soil layer below the deep water an almost threefold decrease of the regression coefficient can be found from July to August; the value of the correlation coefficient changes accordingly, similarly to the decrease of the residual scattering.

It is remarkable that the regression lines of August run almost parallelly, showing thus the similarity of the correlation of the two soil layers with the daily amount of global radiation (*Fig. 3—4*).

Although the degree of reliability of the correlation coefficients are, on account of the small number of cases, unsatisfactory, they do not exclude and even confirm the presumption that in August the strengthening and closing rice stand disturbes and reduces the effect of the global radiation on the trend of the soil temperature. In other words: the plant stand more or less overshades the soil and the water layer from the short wave global radiation [17].

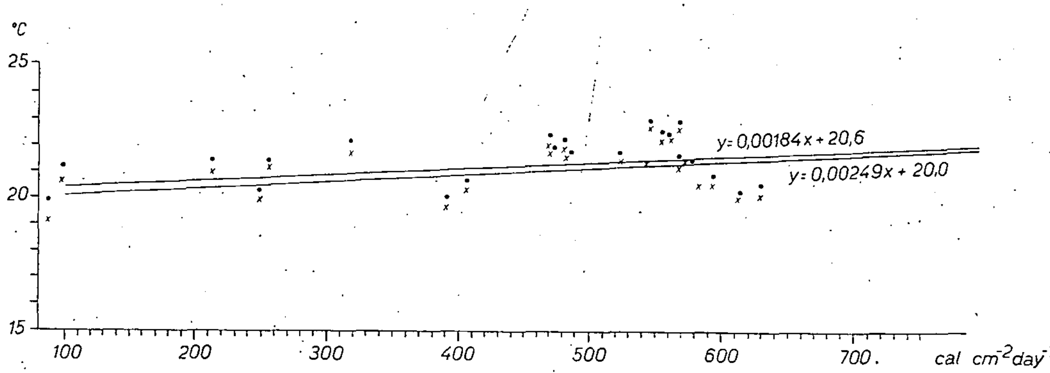

Fig. 4. Correlation of the diurnal mean temperature of the upper soil layer under shallow water with the diurnal sum of global radiation in August.
The S_f layer is the surface-near layer of the soil of „shallow water", the M_t layer is the deeper layer of the soil of „deep water". The values of the diurnal mean temperature of the S_f layer are marked, by x, those of the layers of M_t by dots. The equation $y=0{,}00249x+20{,}0°$ is the equation of the regression line of the S_f layer, and the equation $y=0{,}00184x+20{,}6°$ is the equation of the regression line of the M_t layer (x=cal cm⁻² day⁻¹).

The monthly averages of the daily maxima of the soil temperature decrease from June to September at all the three measuring places at both measuring levels, with the exception that the temperature of both levels of the measuring place "deep water" increases from June to July and decreases only beginning from July. This is in connection with the well-known temperature phase-delay to be found in the annual temperature trend of the deeper soil layers [18].

The monthly trend of maximum temperature differs in June — July from the monthly trend of the daily mean temperature, as it to be expected, since the value of global radiation in June is somewhat higher than that of July, and the effect of it can appear already in the extreme values of the soil temperatures [19, 20].

Similarly to the trend of the monthly averages of maximum temperatures the monthly variations of the monthly averages of daily minima (the other extreme temperature value) is also obvious. In the case of soil layers near the surface the monthly averages of daily minima of the soil temperatures gradually decrease from June to September (with the exception of the layer S_f).

On the other hand, the average monthly minima of the soil temperature of the deeper soil layers and of the measuring place S_f increase from June to July, but decrease from July to September with a gradually increasing tendency.

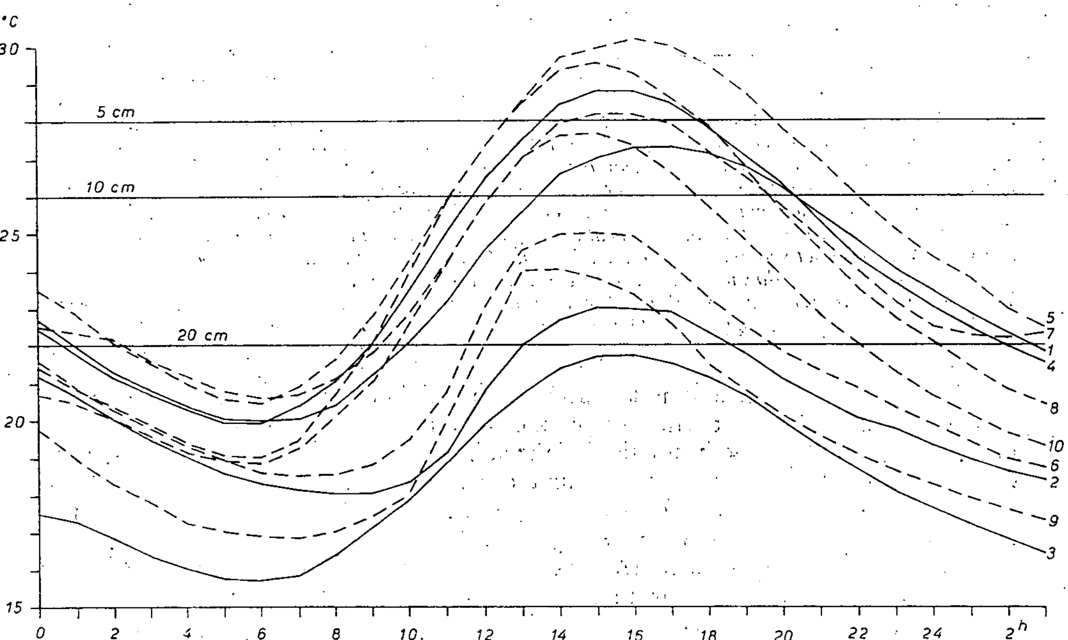

Fig. 5. The diurnal variation of the temperature of the soil of a rice field covered by flooding water of various depths in surface-near and deeper (10—15 cm deep) layers at Szarvas in June, 1975. Key: 1 = deeper layer of the soil of „shallow water", S_t on a cloudless day (June 27); 2 = S_t layer on a cloudy day (June 30); 3 = mean monthly sunshine hours; 4 = deeper layer of the soil of „moderately deep water"; K_t on a cloudless day; 5 = surface-near of layer the soil of „shallow water", S_f on a cloudless day; 6 = S_f layer on a cloudy day; 7 = mean of monthly sunshine hours of the S_f layer; 8 = surface-near layer of the soil of „moderately deep water", K_f on a cloudless day; 9 = K_f layer on a cloudy day; 10 = mean sunshine hour values of the K_f layer.
The horizontal lines are mean values of the soil temperature at 5, 10 and 20 cm depths measured at the agrometeorological station of Szarvas in the third ten days of July.

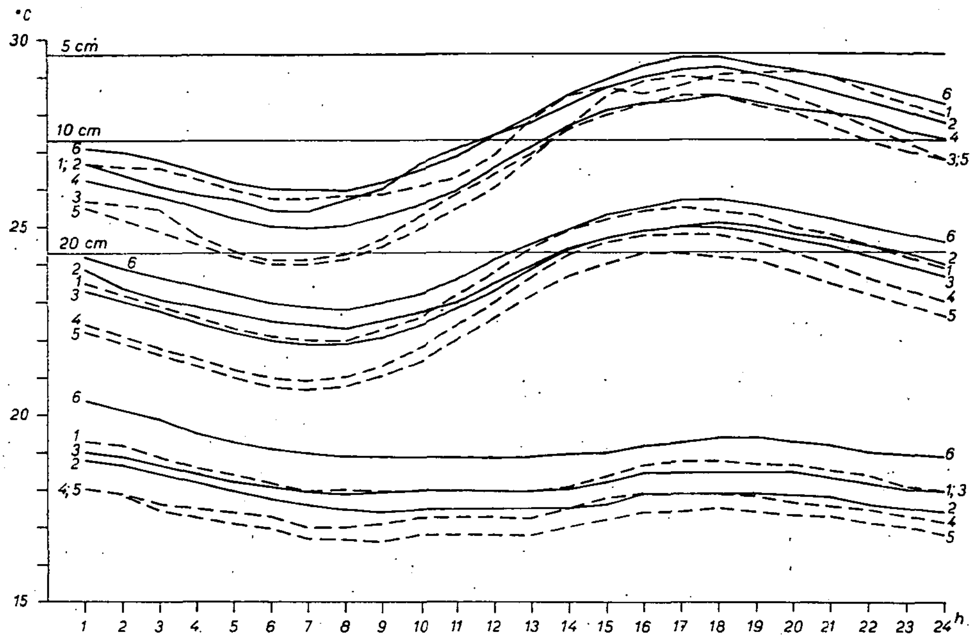

Fig. 6. Diurnal variation of the temperature of the soil of a rice field covered by flooding water of various depths in surface-near and deeper (10—15 cm deep) layers at Szarvas in July 1975.
Key: 1 = surface-near layer of the soil of „shallow water", S_f; 2 = the deeper layer of the soil of „shallow water", S_t; 3 = the deeper layer of the soil of „moderately deep water", K_t; 5 = the surface-near layer of the soil of „deep water", M_f; 6 = the deeper layer of the soil of „deep water", M_t.
The upper set of curves show the diurnal variations of the soil temperature observed on a cloudless day (July 15), the lower set show the same on a cloudy day (July 1), and the middle set of curves show the diurnal variations of the mean sunshine hour values.
The horizontal lines represent the mean soil temperatures observed at 5, 10 and 20 cm depths at the agrometeorological station of Szarvas in July.

Particularly considerable is the decrease of minimum temperature in the first half of September when, by raining off the flooding water the surface of the soil becomes dry and thus the irradiation of the soil may become more intensive. When draining off the flooding water the minimum values of August (about 20 °C on the average) show in the first half of September, both in the layers near the surface and in the deeper ones, lower values (by 8—10 °C).

The effect of the flooding water and of the rice stand influencing the soil temperature, appears most clearly in the monthly variations of the daily amplitude of the soil temperature. Parallelly with the growth of the plant stand the amplitude will decrease in both layers of the soils covered by "shallow" "medium" and "deep" flooding water. The decrease of the amplitude is about 4 °C from June to July and 2 °C from July to August. On the other hand, from August to September the average monthly amplitude of soil temperatures increase by 3—5 °C. The increase of the amplitude is a consequence of the draining of the flooding water and is particularly considerable in the soil layers covered earlier by deep water [21[.

The daily trend of the soil temperature of rice grown with flooding water of different depth is determined in the first place by the development and closeness of the plant stand. The depth of the flooding water influences depending on the agro-

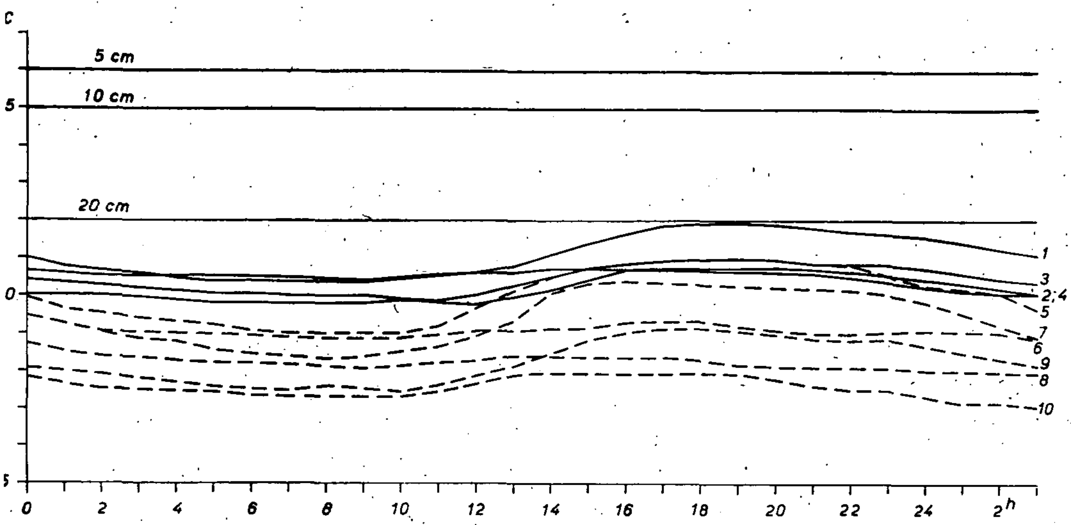

Fig. 7. The diurnal variations of the temperature of the soil of a rice field covered by flooding water of various depths in the surface-near and deeper (10—15 cm) layers at Szarvas in August, 1975. Key: $1=S_t$ layer on a cloudless day (August 21); $2=S_t$ layer on a cloudy day (August 29); $3=M_t$ layer on a cloudless day; $4=M_t$ layer on a cloudy day; $5=S_f$ layer on a cloudless day; $6=S_f$ layer on a cloudy day; $7=K_f$ layer on a cloudless day; $8=K_f$ layer on a cloudy day; $9=M_f$ layer on a cloudless day; $10=M_t$ layer on a cloudy day. The horizontal lines represent the mean soil temperatures observed at 5, 10 and 20 cm depths at the agrometeorological station of Szarvas in the third ten days of August.

technical methods applied according to the development of the stand, — only secondarily the tendency of the daily temperature of the different soil layers. The primary influencing role of the complex climatological ensemble (soil layer — rice stand — flooding water) is proved by the daily soil-temperature trends shown in *Figures 5, 6, 7, 8.* In our Figures we have shown (by lines parallel with the horizontal axis) the mean values of soil temperatures falling to the respective decades (measured at the Agrometeorological Station of Szarvas) at the depths of 5, 10 and 20 cm. The daily trends of soil temperature values (referred to average hour means) and also those of clear and overcast days of months following each other from July to August show a gradually increasing deviation from the mean values of soil temperatures of 5, 10 and 20 cm falling to the individual decades. From the Figures it can be clearly seen that it is in connection with the progressive closing of the plant stand and the development of a connected cluster level. The stand growing more and more dense gradually closes the soil surface and also the deeper soil layers from radiation. In the first half of September the flooding water is — according to the applied growing methods — drained off from the rice stand. As a consequence the gradually drying soil comes into direct contact with the air (having been warmed up during the day). Thus the daily trend of the soil temperature of the different soil layers becomes at the beginning of September — despite the considerably decreased daily global radiation values — similar to the daily trends of soil temperatures in June with markedly wide amplitudes. While in June the soil temperature values of the afternoon hours considerably suppass the ten-year average values of the layers of 5, 10 and 20 cm of the soil surface without water cover, in September the daily soil temperature values remain below these values even in the midday hours.

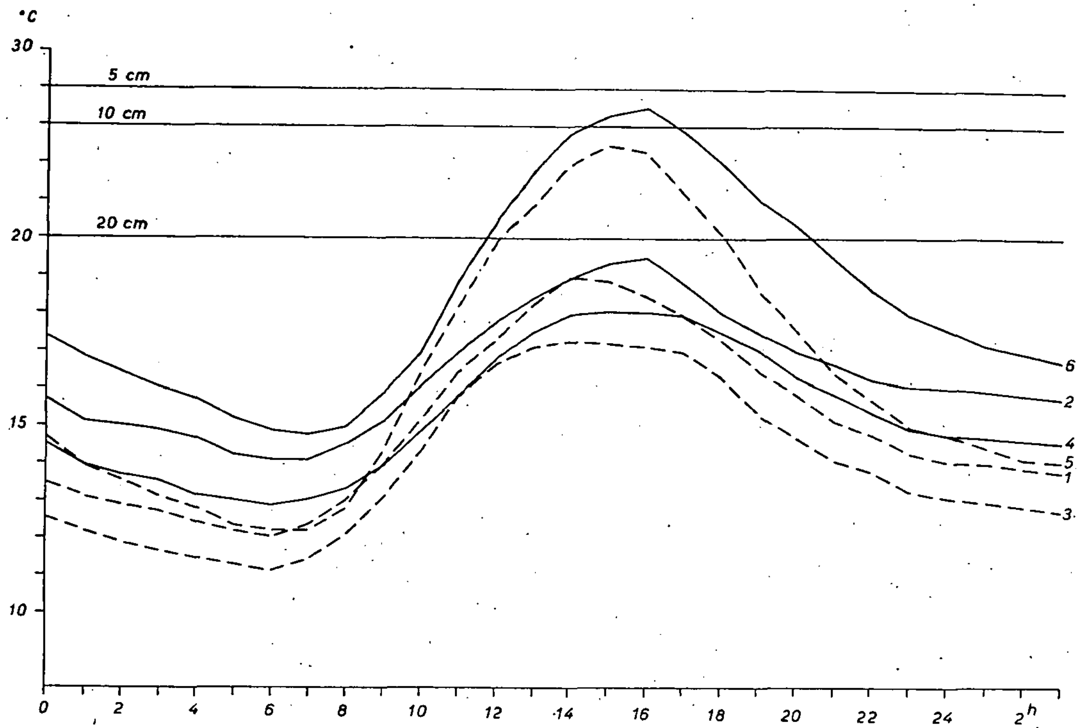

Fig. 8. Diurnal variation of the temperature of the soil of a rice field covered by flooding water of various depths in the surface-near and deeper (5—10 cm deep) layers at Szarvas on a cloudless day in September (Sept. 11) after draining of the flooding water (1975).
Key: 1 = S_f layer; 2 = S_t layer; 3 = K_f layer; 4 = K_t layer; 5 = M_f layer; 6 = M_t layer.
The horizontal lines represent mean soil temperatures measured at 5, 10, and 20 cm depths at the agro-meteorological station in the first ten days of September.

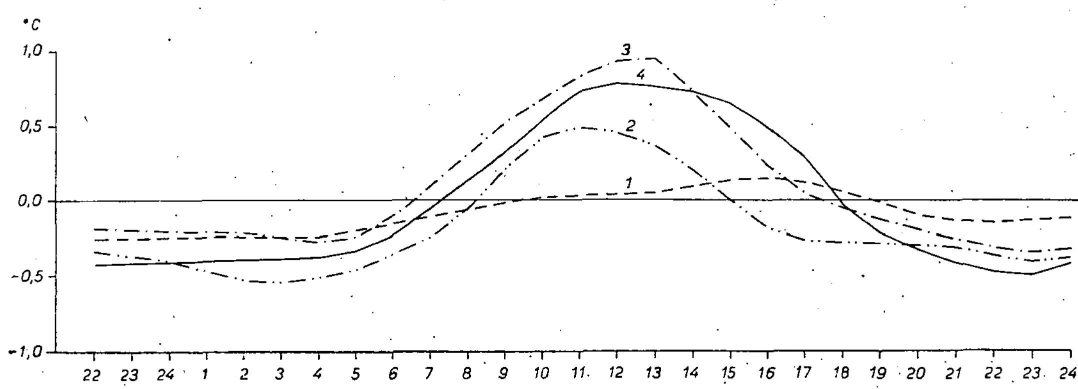

Fig. 9. The hourly variations of the soil temperature in the M_t layer in the case of global radiation of various intensity. Szarvas, July 1975.
Key: 1 = 130 cal cm^{-2} day^{-1}; 2 = 362 cal cm^{-2} day^{-1};
3 = 611 cal cm^{-2} day^{-1}; 4 = 719 cal cm^{-2} day^{-1}.

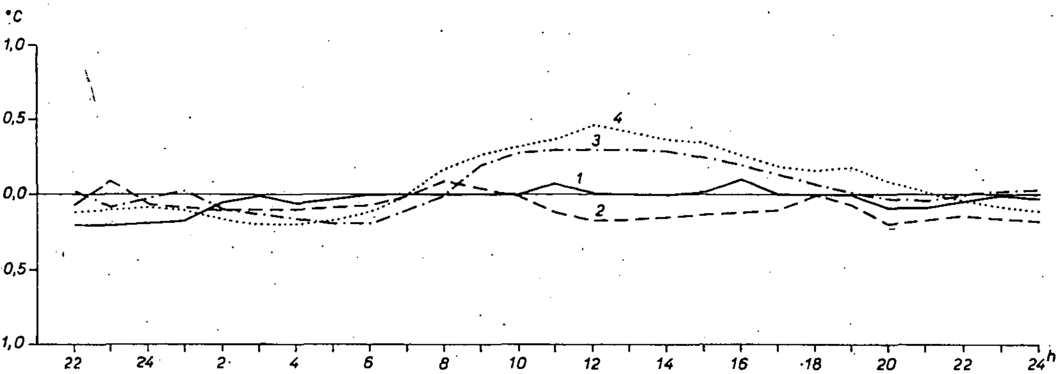

Fig. 10. Hourly variations of the soil temperature in the S_f layer in the case of global radiation of various intensity. Szarvas, August 1975.
Key: 1 = 87 cal cm^{-2} day^{-1}
2 = 319 cal cm^{-2} day^{-1}
3 = 568 cal cm^{-2} day^{-1}
4 = 614 cal cm^{-2} day^{-1}

The marked daily trend of soil temperature in June and September is the consequence of more sparse plant stand and the lack of water cover, while the considerable deviation of the temperature values follows from the decreased global radiation.

In contrast to the previous situations, in July and August the difference of the soil temperature of the night- and day-hours gradually decreases. This can be seen particularly well from the daily trends of the soil temperatures of July. In our Fig. we compared the soil temperatures of a perfectly clear day (15. VII), an overcast day (1. VII) and the soil temperatures of average hourly mean values. In July — as a consequence of the dense plant stand (overshading effect) the temperature values of even the perfectly clear day remain below the average decade mean value of the 5 cm layer of the dry soil.

The soil temperature values of the clear day and the average overcast day run almost parallelly with a difference of about 2—3 °C. On the other hand, the daily soil temperature values of overcast days progress with larger deviations almost completely smoothed deeply below the decade mean values of the dry 20 cm layer.

In order to take into consideration the effect of the global radiation influencing the trend of daily soil temperature we determined the daily trend of the soil temperature values appearing hourly in the soil temperature trend of days with different global radiation (for the case of the soil layer covered by shallow flooding water in July and August) (*Fig.-s 9 and 10*).

It can be stated that the variation of the hourly values of soil temperature is the highest in July during the day. The variation of the hourly values of soil temperature is during the day from 7-8 h to 12-13 h gradually increasing and from 13 to 17-18 h still increasing although in a gradually decreasing measure. After attaining the daily temperature maximum at about 17-18 h [22] an hourly temperature decrease (of equal measure almost during the evening and the night) in the trend of the temperature of the soil layer near the surface covered by shallow flooding water. The largest amplitudes do not appear on the days with maximum global radiation but in the case of a somewhat smaller radiation amount. At the same time, the amplitude is very insignificant on overcast days obtaining less energy (*Fig. 9*).

The plant stand becomes increasingly dense in August, and the almost connected unbroken panicle level strongly overshades the water surface decreasing thus the energy coming to the flooding water and the soil, so the daily trend of soil temperature shows — even on clear days — an almost straightened curve (*Fig. 7*).

In Fig. 9 (showing the variation of the hourly values of soil temperature) we can see also the shading effect of the plant stand shutting out the radiation. On a clear day with an energy income of more than daily 600 cal $cm^{-2}d^{-1}$ the increase of the temperature of the soil in only 0,2—0,3 °C hourly. On account of the overshading effect of the plant stand in August even the maximum values of the soil temperature remain below the August average values (22 °C) measured at the level of 20 cm in the soil without water cover (*Fig. 7*).

But in the first half of September, when the flooding water, is drained off again a certain marked daily trend (although of a smaller amplitude) can be seen (*Fig.* 8) because the dried up soil surface comes into direct contact with the air warming up to 25—30 °C during the day. Thus the agrotechnical method applied influences the growth rate of the plants by changing the climate of the rice stand, stimulating accelerating the full development of the plant and the ripening of its seeds.

References

[1] *Stefanovits, P.:* Magyarország talajai. Akadémiai Kiadó, Budapest 1963.

[2] *Máté, I.:* Adatok tiszántúli réti talajaink genetikájához. Agrokémia és Talajtan IV. 1955/133.

[3] *Nagy, E.:* Mezőcsát-, Mezőtúr- környéki szikes, mezőségi és rétiagyagtalajok ásványtani vizsgálata különös tekintettel a foszfor és káliumtartalmú ásványokra. Földtani Int. Vitaüléseinek munk. VII/1964/61.

[4] *Prettenhoffer, I.:* Átmeneti szikesek javítása kombinált eljárással. Agrokémia és Talajtan II/ 1953/37.

[5] *Szűcs, L.:* A dél-tiszántúli löszhát talajai, különös tekintettel a csenozjom talajok képződésére. I. Agrokémia és Talajtan IX/1960/33.

[6] *Gazdag, L.:* A Maros régi vízfolyásai és elhagyott folyómedrei az Alföldön. Szűcs L.: Agrokémia és Talajtan IX/1960/33.

[7] *Sümeghy, J.:* Tiszántúl Földtani Int. Budapest 1944.

[8] *Vámos, R.—Mérai, J.:* A hazai rizstermelés eredményessége és az időjárás. — Adatok a rizstermeléshez. Szeged, 1957. 5—18.

[9] *Szelényi, F. — Frank, M.:* Az éghajlat és időjárás szerepe a rizstermesztés terén. Öntözésügyi Közlemények, 2 K. 2. 1940. 247—259.

[10] *Szász, G.:* A rizs termesztésének időjárási feltételei a fő termőtájakon. Növénytermelés, 1961. 10. 193—206.

[11] Időjárási Napi Jelentés, 1975, június, július, augusztus.

[12] Országos Meteorológiai Intézet Évkönyvei.

[13] *Károssy, Cs.:* Adatok a rövidhullámú sugárzásforgalom összetevőinek vizsgálatához a Bükkfennsíkon végzett mérések alapján. A szegedi Tanárképző Főiskola Tudományos Közleményei 1973. 85—97.

[14] *Károssy, Cs.:* Különböző rendű mikroklíma térségek rövidhullámú sugárzásviszonyai Kurtabércen. Szeged, 1969.

[15] *Petrasovits, I.:* A rizs különböző mélységű árasztóvizének hőmérsékleti hatásairól. Időjárás 1958. 62. évf. 95—107.

[16] *Wagner, R.:* Die Temperatur des Bodens des Wassers und der Luft in Kopáncs I—II. Acta Climatológica Tom. IV—V. 1—4. Szeged. 1—81.

[17] *Wagner, R.:* Adatok a kopáncsi rizsföldek éghajlatához. Időjárás 1957. 61. 266—277.

[18] *Anderko, A.:* A talaj melegének periódusos ingása. Budapest, 1909.

[19] *J. Boros—Ilona Bárány:* Data Concerning Maximum Temperatures in Variously Fertilized Rice Crops. — Acta Clim. Univ. Szegediensis, Tom. XII. Szeged, 1973. 61—74. pp.

[20] *Ilona Bárány—J. Boros:* Characteristics of the Change of Temperature in Rice Plots of Various Densities. — Acta Geogr. Univ. Szegediensis, Tom. XIII. Szeged, 1973. 105—115. pp.

[21] *Ilona Bárány—J. Boros:* Temperature Conditions in the Microclimate of a Rice Crop. — Acta Clim. Univ. Szegediensis, Tom. XI. Szeged, 1972. 47—67. pp.

[22] *Wagner, R.:* Az árasztás és a növényállomány hatása a mikroklímára. Szeged, 1966. (in manuscript.)