CONTRIBUTION TO THE CLIMATOLOGICAL STUDY OF RICE-GROWING IN THE REGION OF SZEGED

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Zusammenfassung: *(Angaben zur klimatologischen Untersuchung der Reisproduktion in der Umgebung von Szeged.)* Der Reis *(Oryza sativa)* ist eine charakteristische Pflanze des tropischen und subtropischen Monsun- oder Savannaklimas. Nach Weizen ist Reis die zweitwichtigste Nahrungsplanze der Menschheit. Ihre Uhrheimat ist Südost-Asien. Im Laufe der Zeit sind Arten gezüchtet die sich dem Klima akkomodieren konnten und sich auch in Gebieten verbreitet haben wo kein Element der optimalen Klimaerfordernisse befriedigt werden kann.

Schon im 18. Jahrhundert experimentierte man in Ungarn mit der Akklimatisation des Reises eine umfangreichere Reisproduktion begann erst nach dem zweiten Weltkriege.

Die Reisproduktion der 20 Jahre zwischen 1951 und 1970 wurde vom Wetter stark beeinflusst. Mit der Ausnahme des Jahres 1955 wurden die ersten zehn jahre von der Erwärmung charakterisiert, die am Ende des vorigen Jahrhunderts begonnen hatte. Zwischen 1961—70 war das Wetter veränderlicher und unter dessen Einfluss waren die Produktionsdurchschnitte niedriger. In der Umgebung von Szeged gab es hohe Produktionsdurchschnitte in den extrem warmen Jahren. Der Sonnenschein- und Wärmebedarf ist besonders in Juli und August sehr gross, da die Perioden der Halmentwicklung, des Blühens und der Rispenbildung auf diese Zeit fallen. Mangel an Licht aber verzögert die Entwicklung der Pflanze schon vom Beginn der vegetativen Periode. Das Zustandekommen der Bedingungen der Reiskrankheiten wird von einem hohen Dampfgehalt der Luft begünstigt.

Die Durchschnittsproduktion ist in positivem Verhältnis mit der mittleren Temperatur und mit der Sonnenscheindauer. Die Korrelation ist noch enger wenn man die Wetterelemente der verschiedenen Phenophasen betrachtet. Es ist wünschenswert die Untersuchungen im weiteren auf die Phenophasen auszubreiten.

Summary: Rice *(Oryza sativa)* is a characteristic plant of the tropical and subtropical monsoon or savanna climate. After wheat it is the second most important food plant of mankind. Its original habitat is South—East Asia. In the course of its cultivation varieties of it were developed that could adapt themselves to the climate and came into general use also in areas where none of the optimal climatic requirements can be found.

In Hungary experiments for the acclimatization of rice were conducted as early as the 18th century, yet rice-growing on any considerable level started only after World War II.

Rice production in the 20 years between 1951 and 1970 was greatly influenced by the weather conditions. With the exception of the year 1955 the first 10 years were character ized by the warming which had begun at the end of the last century. Between 1961 and 1970 the weather was more changeable and as a consequence of this the average yields

became smaller. In the region of Szeged there were high average yields in the unusually warm years. The sunshine and heat requirements of the plant were especially great in the months of July and August, which comprise the periods of stem formation, flowering, and panicle formation. But the scarcity of light retards the development of the plant from the very beginning of the vegetative phase. High vapor content of the air favors the development of diseases.

The average yield is in correlation with the mean temperature and the duration of sunshine. The correlation is closer when we examine the weather elements in the various phenophases. It is desirable to extend the investigation to the phenophases.

After wheat rice *(Oryza sativa)* is the second most important food plant of the world. Its original habitat is the tropical swampy region of Asia. In the course of long experience with growing and the research work connected with it, varieties of rice have been produced that can endure the climate. Rice has been introduced also in areas where not one of the optimal requirements can be met. In the Soviet Union it has been carried as far north as the 51st parallel.

The botanists L. REINHARDT (1911) and SPRECHER VON BERNEGG (1929) dealt, besides the description of the plant, with its origin and geographical range, which are orienting factsfor the history of the process of acclimatization.

F. F. DAVITAYA (1970), investigating the connections of agriculture and the weather, stated that if the agrotechnics do not change, the weather is responsible for the change in the yield of our crop plants.

In this study we are going to deal with the effect of the weather conditions of a given area on the average yield.

Rice consumption in Hungary has in recent years risen to 3,9—4,1 kg per person. Therefore it is important to investigate thoroughly the ecological conditions of rice-growing, among them the climate and weather.

The acclimatization of rice in Hungary is treated in detail by D. PENYIGEY in this work entitled *„Rice and its Cultivation"* (1962). In our study we will mention a few important stages of the cultivation experiments.

Rice cultivation began in Hungary in the 18th century. (In the 17th century the attempts of the Turkish conquerors at cultivation failed because they imported the rice of Asia Minor and Egytp the vegetation period of which is long.) The Italian families settling in Hungary in the 18th century did much for acclimatizing rice but the production at that time was inconsidarable. Á. BERDE in 1847 described the climatic requirements of rice and reported on successful rice production going on in Bánát and in the county of Temesvár. The climatic and water supply conditions proved favorable in the southern part of the territory of the country at that time now the terrritory of Bácska and Bánát counties in Yugoslavia. The question of setting up rice plantations in the region of the Körös and Berettyó rivers was raised at the beginning of the 19th century. In the second half of the centruy the government dealt officially with the question of rice-growing.

At the beginning of the zoth centruy the absence of suitable rice varieties and the inadequacy of agrotechnichal methods caused a decline in rice production. Only at the time of the First World War was there a new boom.

From that time on experiments for the cultivation of rice also in more northerly parts of the country (e. g. in Pest county) have been going on.

In 1927 the National Rice Board was created, and research work dealing with the problems of rice cultivation started. The intensification of rice production in the 30's is reflected in the even growth of the area sown with rice.

Significant rice production in Hungary started only after the Second World War. From 1951 on large-scale farms took over the role of the small peasant farms.

The rice disease (bruzone) which appeared in 1955 and the decrease in profitableness reduced for a short time the enthusiasm for rice production. From the middle of the 60's onward the use of new varieties in production and the improvement of the profitableness had a favorable effect on production and to this day a moderate growth of the area sown can be observed.

The area sown with rice and its average yield since 1939 have changed in the following way *(MEZŐGAZDASÁGI ADATTÁR, 1965, STATISZTIKAI IDŐSZAKI KÖZLEMÉNYEK, 1969):*

Year	Area	Average yield
1939	99	25,0
1944	8 500	20,0
1950	25 700	19,3
1955	87 500	4,6
1960	48 037	9,3
1969	38 356	13,0

In the 19th century the Italian varieties Nostrale (with long vegetation period)and Mellone (with short vegetation period) were grown in Hungary.

From the 30's of the zoth century onward the *Bánlaki, Varsányhelyi, Restano, St. Giacomo, Arpa Shali, and Dunghan Shali* varieties came into general use.. F. SCHÜLLER and F. SZELÉNYI bred (developed the Hungarian *Ömirt varieties from Dunghan Shali)* a variety of Korean origin, for a long time grown in the Soviet Union. From 1939 on till the end of the 50's the *Dunghan Shali* and *Ömirt varieties* were grown in Hungary.

The Hungarian rice is a starchy variety of excellent quality. Its water absorption capacity is 3 to 4 times its own weight, it does not become sticky, its protein content is 8—12% (GY. BORA 1956, E. TAJTI 1959). However, the resistance of the kinds grown here to disease is not adequate. From the end of the fifties onward several foreign varieties were temporarily grown. From the beginning of the sixties new improved Hungarian varieties, such as *Kákai 203, Kákai 162,* and the early *Szarvasi* began to be used for growing. The productivity, quality, and disease-resistance of the new varieties are good.

Before the second world war the rice requirement of the population was satisfied by import. In the fifties our rice export to the European countries was important, which meant foreign currency income for the national economy. By the end of the fifties our rice export fell to a minimum, and since the beginning of the sixties the need of the country has been met from large bulks of import.

The most important task of Hungarian rice research today is to breed disease-resistant varieties having good qualities.

Fundamental in this subjects is F. SCHÜLLER's bibliographical work (1960), which gives information on the results of the researches at home and abroad,

The symposium of the Agronomic Department of the MTA on the diseases of rice (1958) attests the extensiveness of the Hungarian researches. Among others the symposium concluded that the weather has an important role in the creation of the environmental conditions favorable to bruzone (R. WAGNER, J. PODHRADSZKY, J. KULIN, S. POLGÁR, G. PÁLFY, J. SIMON). In connection with the improvement and production of rice the work ot the researchers of the Research Institute of Szarvas for Irrigation and Rice cultivation is very important in our days.

Our paper contributes a few data to the investigation of the climatological conditions of rice production.

R. WAGNER has dealt extensively with the climate of the Hungarian paddy fields and rice stands (1957, 1966, 1967). According to his findings the weather has a direct and — by creating favorable environmental conditions for the rice diseases — an indirect effect on rice production.

I. KISS (1959) brought the bruzone damage of 1955 into connection with prefrontal weather conditions.

N. BACSÓ (1963) indicated the line Barcs—Szigetvár—Székesfehérvár—Szolnok—Debrecen as the northern boundary of rice-growing in Hungary. This line is the northern boundary of the 21° isotherm and the 3100 °C heat total. The vegetation period is 125—140 days. In this period the total of the sunshine duration is 1308—1400 hr. According to E. OBERMAYER and D. BERÉNYI rice needs a daily mean temperature of 13 °C during germination, 22—24 °C during flowering, and 19 °C during ripening.

In Hungary rice-growing by flooding is cultivated. Rainfall in moderately warm years poor in sunshine has a negative effect on the average yield.

R. WAGNER (1957) found that from the point of view of rice diseases it is not sufficient to investigate the monthly mean values of the climatic elements of given area.

Our present paper dealing with the investigation of the vegetation period serves as a basis for the study of rice stands and the microclimate.

Keeping the above things in mind we search the connections between the weather of the vegetation period (1 April—30 September) and the average yield of rice in the southern Alföld (Great Plain) on the basis of the meteorological data of 20 years (1955—1970). (The average yield data refer to Csongrád county, the meteorological data are observations of the climatological station of the University of Szeged.)

MRS. SIMON, IBOLYA KISS (1960) tried to distinguish the phenophases of rice. In investigating the climatic conditions of the different years special attention is given to the critical periods of panicle development and flowering. On the basis of long experience with several varieties we can say that the period of panicle development and flowering generally lasts from July 25 to August 5.

In this period the light requirement of the plant is great. In the development of the flower buds the measure of illumination is a decisive factor. The heat requirement of the plant is a mean temperature of 22—24 °C at this time. Filling of the spikelets is hindered by cooling of the water.

The weather of the vegetation period

The weather of the 1950's was characterized by the warming up which began at the end of the last century (M. KÉRI 1967). In the 1960's a cooler, more changeable period began.

This can be measured also on the basis of the amount of the sunshine hours of Szeged. Between 1951—1960 the average of the sunshine hours of the vegetation periods was 1576,4 hours, between 1961—1970 it was 1547,9 hours, the difference being 28,5 hours. This difference is not evenly distributed over the six months of the vegetation period. The greatest difference is found in the month of August covering the periods of panicle development, flowering and filling of the spikelets. Between 1951 and 1960 the average duration of sunshine in August was 20,9 hours more than in the decade 1961—1971. In the other months of the vegetation period this difference does not exceed 6 hours.

The more changeable summer weathers affected of course the development of our cultivated plants. The rainy weather was favorable for some plants but unfavorable for rice, which has a great heat requirement.

In the fifties — if we take into consideration also the year 1955, in which the weather was extreme in several respects — the average yields of rice were higher than in the sixties. No doubt a more changeable period in the weather contributed to this. Searching for the cause of the variations in the average yields, we present the diagram of the mean temperature, rainfall and sunshine duration in each month of the vegetation period of 20 years (Fig. 1). (The scale on the left shows the absolute values, the one on the right shows the + and — deciations from the mean of 50 years.)

The mean value of the average yield of 20 years calculated for 1 Hungarian cadastral acre (0,7 hectare) is 22,2 cwt. The yield was below the average in seven years (1955, '59, '61, '64, '65, '66, '70), above the average in 12 years, and agreed with the average in 1 year.

Now let us examine the weather of the vegetation period in the seven years with poorer yields.

R. Wagner (1957) and I. Kiss (1959) examined the year 1955 of poor yield by a day by day analysis. We give here an overall characterization of the vegetation period.

The spring began with adverse conditions. The mean maximum and minimum were very low in April (12,9 and 3,7 °C respectively); the mean temperature was also the lowest in 20 years (8,5 °C) at that time, i. e. 2,9 °C lower than the average of 50 years. There was no scarcity of sunshine, indeed there was a surplus of 25,1 hours.

In May and June there was little precipitation. There was no significant warming up. The mothly mean temperature amplitude was rather great in both months. (10,1 and 10,8 °C respectively).

By creating favorable conditions for plant diseases the cool summer caused damages in the critical periods of panicle development and flowering of rice. The large amount of rainfall (90 mm more than the average of 50 years) was accompanied by heavy cloudiness. The duration of sunshine was 94,5 hours less than the average of 20 years. August was still poor in sunshine, with little evaporation, and the relative humidity (72%) had the second highest value in 20 years.

In 1959 the weather of April and May agreed with the average. In June there was were 102 mm of precipitation. In July there was lasting cloudiness and the duration of sunshine was 46 hours less than the average of 20 years. The weather of the remaining part of the vegetation period did not differ from the usual. The unfavorable weather preceded the generative phase, this is why there was no similar decrease in the yield as in the year 1955.

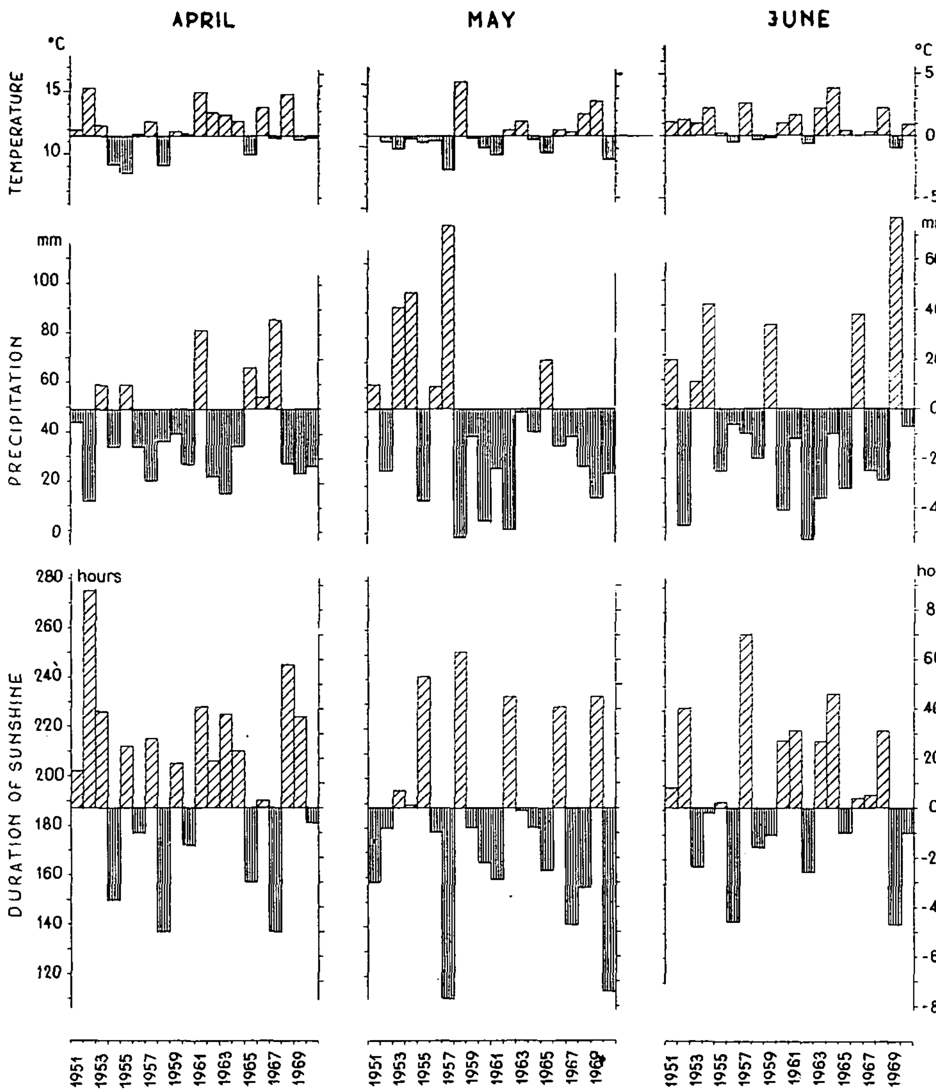


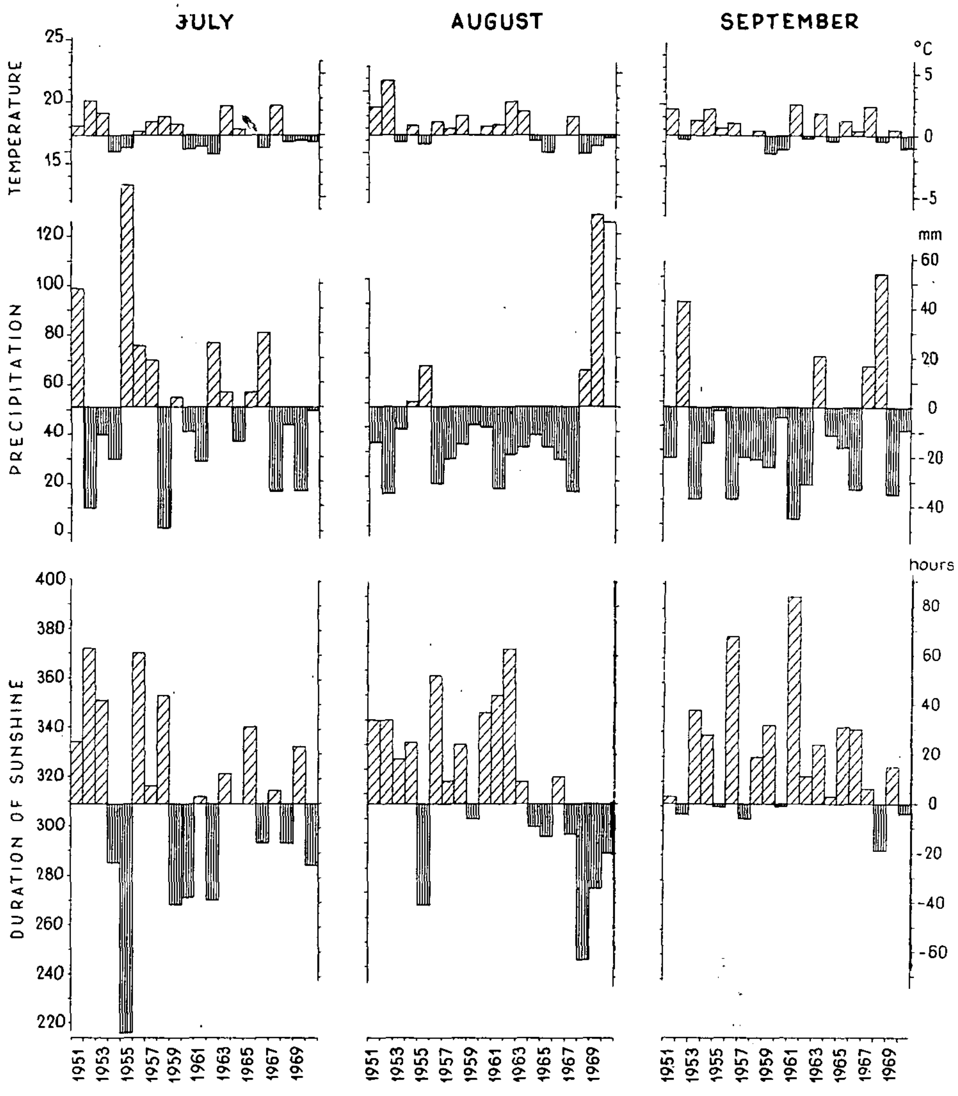
Fig. 1. The monthly mean temperature total precipitation and sunshine hours in the vegetation period between 1951 and 1970 at Szeged. The horizontal axis shows the average of 50 years.

At the end of April and in May in 1961 the cool weather hindered the development of rice. In May the mean maximum (19,2 °C) was the lowest after 1957. The monthly mean temperature was 1,5 °C lower, the duration of sunshine 38,5 hours less than the average of 50 years.

In the initial phase of vegetative development the plant did not receive the necessary amount of light.

Although June and July with normal weather were followed by sunny, dry August and September, the earlier unfavorable effects of the weather in the vegetation period reduced the average yield.

In 1964 the spring was cool everywhere in the country. In Szeged the weather in April and May was the same as the average of 20 years. The mean maximum, minimum and the mean temperature were the highest in this year if the months of June are compared. In June and August periods of intense warming up and cooling off alternated. In the first decade of August the duration of sunshine decreased, and this had an unfavorable effect on the filling of the spikelets.



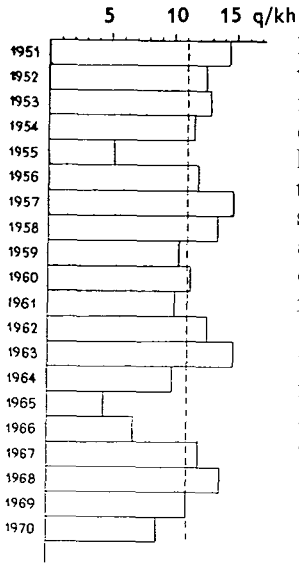


Fig. 2. The average yield of rice in Csongrád county between 1951 and 1970. The broken line is the mean value of the average yield of 20 years. The unit q/kh means 2 cwt/0,7 hectare.

The lowest average yield (8,8 cwt/Hca) was in 1965. In April and May the reainfall was higher, the mean temperature lower, than the average of many years. June was characterized by the scarcity of sunshine. In June and July the air humidity was high (71 and 67 % respectively). In August the mean temperature was 2 °C lower and the duration of sunshine 21 hours less than the average of 20 years. The alternation of warming and cooling every 5 to 6 days in August had an unfavorable effect on the flowering and grain development of rice.

The yield increased somewhat in 1966, yet this was the year with the poorest harvest. The favorable spring weather was followed by a rainy June and July. In June the rainfall exceeded the average of 20 years by 44,4 mm and in July by 29,7 mm.

The large amount of rainfall was very unfavorable. In the period of stem formation and panicle development of the plant there was no lasting rmwa spell. In July the duration of sunshine remained 15,4 hours below the average of 50 years.

The year 1970 was characterized by a scarcity of sunshine. In none of the months of the vegetation period did the duration of sunshine reach the average of many years. The greatest scarcity of suninesh was in July and August with 26,9 and 28 hours negative deviation. Between July 15 and 18 there were 35,3 mm of precipitation. In 4 days the mean temperature fell morethan 10 °C.

In August the precipitation exceeded the average of 20 years by 80 mm. The cloudieness was lasting. The air humidity reached 68 %.

The weather of July and August greatly influences the amount of the yield that can be expected as these two months comprise the periods of stem forming, panicle development and filling of the spikelets.

Let us now survey the diagrams of the mean temperatures and the mean maxima and minima of June and August in 20 years. (Fig. 3).

Yields were higher than average in the years when the mean temperatures of July and August, the mean maxima were much higher than the average of 20 years.

In the years with poorer harvest the mean temperature and the mean maxima and minima were below the average or near to it.

In the years 1955, '65, '66 and '70 the unfavorable July and August weather was responsible for the low average yields.

In the following we try to find connections between the average yield and the different weather factors in the course of 20 years using mathematical statistical methods.

The character of the connection is first determined by the method of dot diagrams. The mean temperature of July and August, as well as the duration of sunshine in August, is in positive correlation with the average yield. (Fig. 4).

When this method was used, the precipitation showed no close correlation with the average yield. Using this method we got an answer also to the question, which factors must be compared with the help of the linear regression of two variables.

The dependent variable is the average yield, independent variables are the values of the different weather elements. On the basis of the calculation of the correlation with two variables we obtained the value of the correlation coefficient (r) and we drew the regression lines (Y' =Y ± bx). We determined the square difference between the real and the calculated values of the depen dent variable or the standard error (S_y) and the relative error expressible in percentage (H_r).

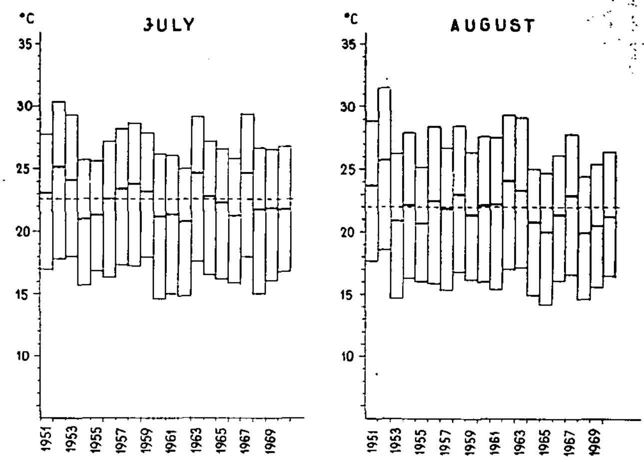


Fig. 3. Temperature amplitudes in July and August. The toplevel of the columns shows the maximum, their lower level the mean minimum. The continuous line in the columns indicates the monthly mean temperature, the broken line the mean temperature of 20 years.

The correlation coefficient of the mean temperature in July and the average yield is 0,4464, the correlation coefficient of the mean temperature in August and the average yield is 0,4263. The linear correlation exists, but it is not close. If we consider the mean temperature in July as an independent variable, then 50% of the points is at the Sy value and 60% within the permissible 2 Sy values; this distribution is not correct, the relative error is 23,6%.

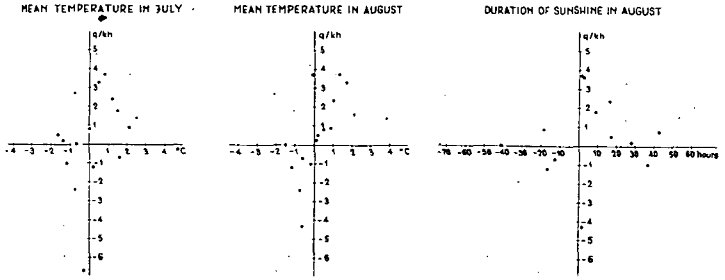


Fig. 4. The correlation of the average yield with the mean temperature of July, the meantemperature of August, and the duration of sunshine in August. The vertical axis shows the deviation from the average yield of 20 years, the horizontal axis shows the deviation of he weathert factors from the average of 20 years.

Taking the mean temperature in August as an independent variable, 55% of the points will be within the Sy value and 75% of them within the 2 Sy value. Here too, owing to some years with poor average yields, the relative error is great, 24,1%.

In the case of the duration of sunshine in August the correlation coefficient shows a closer correlation, but the relative error is great here too.

In the case of the monthly mean values we have a more realistic approximation if we examine the variation of the average yield as a function of the weather factors in the period of panicle development and flowering (July 25 to August 5). (In each year we took asabasis the average of the sums of the daily mean temperature and the duration of sunshine in the above-mentioned 12 days.) In this case we did not take into consideration on the basis of the monthly means the years 1955, '57, '63, '65, '66 and '68, which differed much from the average regarding the yield or the weather.

The totals of the mean temperature and the duration of sunshine are in linear correlation with the average yield; their unit growth causes an increase in the average yield (within optimal limits).

The correlation coefficient for the mean temperature is 0,3705, for the duration of sunshine 0,4005. Here too, the correlation coefficient shows no close correlation.

The regression line affords information about the nature of the correlation. (Fig. 5). In the case of the temperature 85,6% of the points, in the case of the duration of sunshine 85,7% of the points is located within the limits of the allowed 2 Sy, the relative error is 12,0 and 11,5! respectively. This distribution may be considered normal.

An important result of the calculation is the parameter b, which shows to what extent the unit change of the independent variable (in this case the weather factors) influences the value of the dependent variable (average yield). As the connection between the different variables is not strong, the values of the parameters can only be considered orientational.

The parameter of the mean temperature and average yield is 0,38; the parameter of the duration of sunshine and the average yield, 0,79.

Rice is an acclimatized plant in Hungary, so it is understandable if in the most critical period of panicle development and flowering even a slight change in the weather may result in a considerable decrease in yield. Determination of the correlation for just one phenophase is not sufficient. The calculation must comprise all the phenophases. It is possible that in the less sensitive phenophases of the plant the connection will be more clearly demon strable also by mathematical methods.

Summarizing we

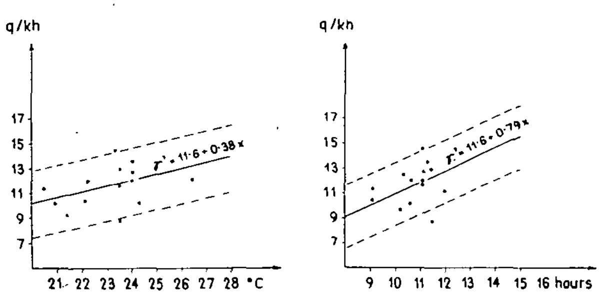


Fig. 5. Regression of the average yield with the mean temperature and the duration of sunshine (between July 25 and August 5). The continuous line is the regression line, while the broken line is the permissible limit of the standard error (2 Sy).

can say that one of the most important conditions of rice cultivation in Hungary is the weather. The average yield is reduced by scarcity of sunshine, cool or rainy weather in the vegetation period. There were high average yields in the extremely warm years. The sunshine and heat requirement is greatest in the months of July and August, which comprise the periods of stem forming, panicle development and flowering. But scarcity of light delays the development of the plant already from the beginning of the vegetative phase. Too much humidity in the air is harmful because it creates conditions favorable to diseases.

Trying to find connections between the average yield and the weather factors by mathematical statistical methods we found a positive correlation between the average yield and the mean temperature as well as between the average yield and the duration of sunshine. On the basis of these facts it can be said that the monthly mean values are not adequate for the determination of the measure of the correlation. The investigation must comprise the phenophases also. With the help of mathematical statistics we can later attempt to foretell the probable volume of the rice harvest.

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