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"PHD THESIS"

DRY MATTER ACCUMULATION AND MOISTURE LOSS DYNAMICS OF GRAIN YIELD IN DIFFERENT GENOTYPE MAIZE HYBRIDS

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DEBRECEN
2003.

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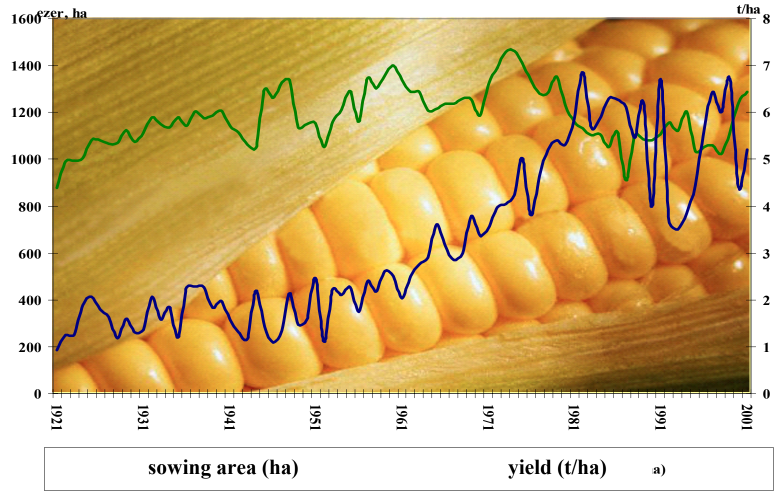
1. INTRODUCTION

Maize is one of the most important plant cultures in plant cultivation. It makes up 70-72% of the Hungarian forage consumption. Its sowing area steadily exceeds 1000 hectares since the end of the 80's (figure 1.).

Figure 1. Formation of maize sowing area and yield average in Hungary **(Source: KSH)**



Between 1960-81. Hungary was third in the world with its yield quantity of maize per unit area while regarding genetic advances, the annual 151.5 kg/ha yield increase put Hungary in first place.

However, this intensive period did not only have outstanding results, but also unfavorable consequences. During this period, the quantitative approach was typical, thus economic optimal and environmental protection aspects were disregarded.

The spreading of quality approach means that the primary aim is to raise the standard of agrotechnical factors. Breeding and hybrids with high genetic potentials play a significant role in achieving the results. Especially good economic results can be achieved with the application of hybridspecific cultivation technologies, but the testing and evaluation of new hybrids every year is one condition that has to be met.

In plant cultivation, the energy invested during the technological operations multiplies in the product. With the help of the Sun's energy and the fertility of the soil, 19,4 GJ energy accumulates in a hectare of maize which equals 2,7 energy utilization coefficient. This factor gradually decreases in specific phases of processing (drying, storing, forage mixing, etc.) and if the final product is an animal product then its value is below one. One of the most important possibilities to improve the energy utilization coefficient can be found during the phases of harvesting and crop-drying, by cultivating such hybrids that have a lower water content at harvest on the one hand and by energy efficient dehydration on the other hand.

Decreasing energy consumption of drying is of high significance, if we examine the consumption of direct energy sources. Depending on yield average, drying contributes to the consumption of 60-80% of direct energy sources (BEKE, 1997.).

On the basis of data by Szabolcs Gabona RT. the gas consumption per 1% water content decrease is 2,34 m^3/t/%.

Drying is the costliest factor from all the supplemental processing expenses of maize cultivation, it makes up about 40-45% of total expenses (table1.).

Table 1. The expenses of specific operations in maize cultivation
(Source: Agrárgazdaság Ltd. 2000.)

Operation	**Cost**(Ft/ha)
Fertilizer application	1500
Disk	2000
Ploughing	9000
Dragging	2000
Fertilizer application	1500
Combinator 2X	2000
Sowing	2500
Chemical (weed control)	2000
Cultivator 2X	2000
Harvesting	10000
Transportation	2700
Drying (10% dehydration)	*30000*

6. LIST OF SCIENTIFIC PUBLICATIONS IN THE TOPIC OF THE THESIS

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NAGY J. - MEGYES A. - RÁTONYI T.- HUZSVAI L. - SZABÓ GY. - **DOBOS A.** - SUM O. (2000): The effect of tillage and fertilization on the yield of maize (*Zea mays* L.) in droughty and favorable years. Acta Agronomica, (in print)

5. RESULTS APPLICABLE IN PRACTICE

- The length of growing season for specific hybrids, expressed in days, depends largely on year and can only be used for a specific growing site in a specific time. Expressing growing season in heat sum depends less on year and growing site and reliably characterizes the length of the phenologic period for specific hybrids.

- Fertilization affects the moisture content of grain yield. Increasing fertilizer doses and correlation between grain moisture content can be characterized by a quadratic function with a minimum value.

- Due to the effect of fertilization, the number of grains increases significantly, justifying that nutrient supply (with given water supply) favorably influences insemination and yield. We have found, that there is no significant difference in the slope of the linear section, namely there is no significant difference in the rate of the grain filling and the in the specific treatments, fertilization increases the length of grain filling.

- On the basis of quadratic curve for fertilizer utilization and considering year, we have determined the fertilizer reaction of the examined hybrids. In the first section of the quadratic function, the value of slope is great and we experience great surplus yield at low nutrient levels. From the second section, the slope of the function gradually decreases, then around the yield maximum a wide plateau occurs where, with the increase or decrease of fertilizer doses, the quantity of yield only changes by a small extent. Our examinations have proved, that in economic maize production achieving maximum yield cannot be priority, nutrient supply has to planned for the first section of the quadratic function.

Due to high energy prices and the rapid increase of drying expenses, the demand for maize hybrids with shorter growing seasons is increasing. Cultivation requires such hybrids, that have a 20-25% grain moisture content, thus are suitable for storage with less dehydration. This is important not just from the aspects of energetics , but the content and dietetic effects of the forage are also more favorable. Hybrids with slower moisture loss are also suitable for wet storage technologies.

In order to avoid expenses and work surplus at harvest, it is expedient to cultivate hybrids with longer and shorter growing seasons as well as hybrids with slower and faster moisture loss characteristics in appropriate ratios. However, we need to know the parameters of the hybrid (length of growing season, time of flowering, dynamics of moisture loss, rate of grain filling etc.).

I have tried to contribute to the solution of these thoughts and tasks with the objectives of my research while providing results that can be directly utilized in agricultural practice.

I have investigated:

- the most important environmental factors influencing the dynamics of moisture loss
- the most important phases of moisture loss
- the effect of growing site and hybrid specification on the dynamics of moisture loss
- the effect of fertilization on the dry-matter accumulation and moisture loss dynamics of maize in hybrids with different genotypes
- the effect of fertilization on the yield elements of maize
- the fertilizer reaction of specific hybrids in different years

2. MATERIALS AND METHOD

2.1. The setup of the tillage experiment and characteristics of the soil

Sample taking was carried out on two determinative cultivating locations for maize cultivation, in Debrecen and Szeged.

Debrecen

The three factorial (fertilization, irrigation, genotype) experiment was initiated by Debrecen University, Center of Agricultural Sciences in cooperation with KITE at Nádudvar in 1978 and was set up at the Experimental Station at Látókép of Debrecen University. The research work was supported by the National Scientific Research Fund since 1991. Within its framework the productivity, natural nutrient utilization and fertilizer reaction of 10 maize hybrids were examined annually. The experiment was set up in four repetitions, in split plot arrangement, the main plot (120 m^2) fertilizer treatment, the sub-plots (15m^2) the maize hybrids. We have developed plots of identical size for destructive sample takings.

The Experimental Station can be found at the Loess Ridge of Hajdúság, its soil is deep humus layer lowland chernozem with lime deposits formed on loess. Its physical characteristic is medium bound loam. Groundwater level is at 5-8 meters. The most important physical and chemical charactersitics of the soil at the experimental station are summarized in tables 2. and 3. (RÁTHONYI 1999.).

Table 2. Important physical characteristics of the soil at the experimental area

depth	area with drainable silt	Soil plasticity	higroscopicity	weight-volume	pore-volume	minimal water capacity	Non-available
cm	Li%	K_A	hy	g/cm^3	P%	VK $_{mintf\%}$	HV $_{tf\%}$
0-20	56,8	42	2,25	1,41	46,7	33,7	12,69
20-40	58,6	43	2,25	1,43	46	31,1	12,87
40-60	57,1	43	2,13	1,31	50,5	29,1	11,16
60-80	57,5	44	2,51	1,29	51,3	28,6	12,51
80-100	58,6	48	2,07	1,30	50,9	29,1	10,76
100-	54,1	47	2,18	1,24	53,3	27,4	10,81
120-	55,3	46	1,91	1,24	53,3	27,8	9,47

4. NEW SCIENTIFIC RESULTS

- We have proved that growing season expressed in heat sum contains information, which can be better utilized in practice.
- In a specific year water maximum forms at almost the same time (2-4 days)
- There is a strong correlation between the maximum water content of the grain and the length of the generative period.
- The rate of moisture loss is primarily determined by temperature.
- The moisture loss dynamics of a specific genotype can be characterized by a common regression line irrespectively of year (19 hybrid – 15 hybrid)
- The change of water content can be characterized by a common regression coefficient but the constants differ from each other significantly.
- The number of grains per cob increases as a result of fertilization.
- Fertilization does not influence the rate of grain filling but increases its length significantly.
- Due to the effect of fertilization there is no significant difference in the moisture content of maize grains, in the beginning of the generative phase.

Due to the effect of fertilization, moisture content at harvest decreases.

We have examined the effect of fertilization on grain yield, at six levels – in unfertilized and five different fertilized treatments. The fertilizer doses 1N: 0.75 P_2O_5: 0.88 K_2O constant ratio NPK doses and their x2-x5 quantities, in which the basic dose was 158 kg until 1995, and 89 kg/ha from 1996. We have included those hybrids from all the examined ones, that had yield data of minimum three years.

In the examined years, the multiple R values were characterised by a broad interval (0.53-0.89). The linear and squared member of the equation, on the basis of the t-probe were also significant at 0.1% level. In years of drought, smaller R values have characterised the fitting of the quadratic function, because the relative deviation of the basic data was greater.

In the six years the average error of yield estimating was between 500-1700 kg/ha. A relative wide interval is due to the extreme characteristics of years, 1994 and 1995 was very droughty, while the years of 1998 and 1999 were characterised by a favourable precipitation. In the particularly droughty year of 1995, the severe water deficiency occuring during flowering has increased infertility of grains and caused the abortion of grains in the lag period. Maximum yield, on the basis of the equation, developed on the control, unfertilized plots. Fertilization relative greater water deficiency has caused yield depression, in the case of both hybrids (AW 043 SC, Occitan SC) and we have measured significantly smaller yield in the fertilized treatments.

We have evaluated the natural nutrient- and precipitation utilization of specific hybrids, and their fertilization reactions.

On the basis of the analysis we have found that by fitting a quadratic equation, considering the many years of yield data, shows a medium or good correlation between yield and fertilization. In the examined years the error of estimating is relatively low, the fertilizer effect is to a similar extent. The reason for this is, that the characteristics of the examined years (precipitation, average temperature etc.) were similarly favourable, yields were squares without irrigation. The dominance of the linear member's yield increasing effect was also the result of the favourable years.

Table 3. Important chemical characteristics of the soil at the experimental area

depth	Chemical		$CaCO_3$	humus	Total N	AL-soluble	
cm	H_2O	KCl	%	%	%	cm	H_2O
						ppm	
0-20	7,3	5,6	0	2,72	0,150	133,4	240
20-40	7,2	5,4	0	2,31	0,120	48,0	173,6
40-60	7,2	5,8	0	1,68	0,100	40,4	123,0
60-80	8,0	7,2	1,1	1,02	0,086	32,4	96,5
80-100	8,4	7,5	11,64	0,81	0,083	39,8	93,6
100-120	8,4	7,5	10,63	-		40,6	86,1
120-140	8,4	7,5	7,5	-		31,6	78,0

Szeged

The KITE PLC. at Nádudvar has initiated its experiment to examine the ripening biology of maize hybrids in cooperation with the Szeged Crop Research Institute (CRI), at Szeged. Annually, they examine around 12-20 commonly cultivated hybrids in three repetitions. There are 50 plants in a plot, in 70 x 24 cm bounds, with 59500 plant density per hectare.

The farm of CRI at Ságvár is located in the small region of the Southern-Tisza valley.

The soil type is solonetz, chernozem meadow soil with high lime content, loamy or sand-loamy structure. Beyond the salinity occuring in the B-layer, the exchangeable sodium content exceeds 5% of the S-value.

The pH 8-8,4, nutrient supply from nitrogen is medium, P_2O_5 and K_2O are good. Groundwater is high in sodium and is located at 1.5-3 meters deep. The soil has good water infiltration, at times of high water levels it can become over-moisturized.

2.2. Calculating weather data and climatic parameters

Daily precipitation was determined with local measuring while data regarding daily radiation and temperature were provided by the Agrometeorological Observatory of the Center for Agricultural Sciences of Debrecen University and the National Meteorological Service, Budapest. We have examined the amount of precipitation during growing season, the formation of effective heat units in the vegetative and generative phases as well as potential evaporation and water supply from the agrometeorological parameters.

Calculating beneficial temperature sums

The daily beneficial temperature sums were determined with the algorithm by RITCHIE et al. (1994).

The general formula of beneficial temperature sum is the following:

$$t_d = \sum_{i=1}^{n} \left(T_a - T_b\right)$$

where T_a = the daily average air temperature; $T_a = (t_{min} + t_{max})/2$

T_b = basis temperature; $T_b = 8\ ^{O}C$.

The error of the formula is that the daily distribution of temperature is not symmetrical, thus significant differences can occur between the actual average and the average temperature calculated from the daily minimum and maximum.

The above mentioned error can be avoided with the applied algorithm because it breaks the 24 hours of the day down to eight, three hour long periods. Calculating the coefficients of the time periods is done with the help of a cubic equation:

tmfac(i) = 0.931 + 0.114 * i - 0.0703 * i ^ 2 + 0.0053 * i ^ 3

i=1…8

The average temperature of the period j:

ttmp = tmin + tmfac(j) * (tmax - tmin)

Depending on how high the value of the actual three hour period is, the equation is modified:

- if maximum temperature is below the basis temperature then the beneficial temperature sum is zero

tmax < tbase

dtt = 0

- if the temperature of the calculated period is within the optimal range, then it increases the daily beneficial temperature sum with an eighth weight ttmp > tbase és ttmp <= 34

dtt = dtt + (ttmp - tbase) / 8

- if the temperature of the three hour period is between 34 and 44 degrees, then it decreases the beneficial temperature sum with a correction coefficient ranging from 0,1-1,0.

ttmp > 34 and ttmp < 44

dtt = dtt + (34 - tbase) * (1 - (ttmp - 34) / 10) / 8

ahol	dtt	=	beneficial temperature sum (^{O}Cnap)
	tbase	=	basis temperature (^{O}C)
	ttmp	=	calc. temperature of the j-th period (^{O}C)
	tmax	=	daily maximum temperature (^{O}C)
	tmin	=	daily minimum temperature (^{O}C)

In the examined years the multiple R values were characterised by a narrow interval (0.84-0.93), on the basis of the F probe, the effect of fertilizer proved to be significant in all years at 0.1% level. The linear and squared members of the equation, on the basis of the t-probe were also significant at 0.1%. In both years the dominance of the linear member was typical, the depressive effect of the squared member was present to small extent.

In order to examine the reliability of differences between fertilizer treatment averages we have applied Duncan test. With the examination we have found that in the fertilizer reaction of specific hybrids, there is deviation in averages of years. The grain number of DK 471 SC does not change significantly from 60 kg/ha treatment upwards, we have not measured a significant increase in grain number. The grain number increase of MV 484 SC is steady, maximum grain number was achieved with 120 kg N/ha treatment.

Fertilization promoted **grain filling**. We have found, that in the slope of the linear section, that is in the rate of grain filling, there is no significant difference among the specific treatments, and fertilization increases the length of grain filling period.

At time of harvest, we have examined the effect of fertilizer treatments on thousand grain weight. We have found, that better nutrient-supply has significantly increased the thousand grain weight of both hybrids.

When comparing the two years, in the average of treatments – grain filling lasted until 320 °C days – in 1998, while in 1999 due to the favourable water supply, the linear section of grain filling extendedby around 100°C days.

We have examined the effect of fertilization, at different times of grain development, on **moisture content** of maize grains.

We have found, that in the beginning of the generative phase, there is no significant difference among the specific treatments.

In 1998, from the end of August we have found significant differences among the water contents - verifying the effect of fertilization - of the specific treatments. Due to the effect of fertilization, the water content of grains has decreased by the time of physiological ripening. The minimum of water content, was in fertilizer treatments of 60 kg N/ha at both hybrids in 1998, so the greater fertilizer treatments have increased water content, while in 1999, the water content of hybrids has decreased significantly until 150 N kg/ha dose.

In 1999, due to the favourable year, we have measured lower water content values at both hybrids at the time physiological ripening than in 1998. The explanation of the phenomenon, that the formation of the black layer occured later, grain filling was not hampered by any external factors.

There is strong correlation between the amount of maximum water of a grain and the length of the generative phase of a specific hybrid in a specific year. In case of better water supply (1998) greater water maximum occured, which indirectly enhanced a longer and more intensive dry matter infiltration.

The **intensive phase of moisture loss** lasts from reaching the water maximum until physiological ripening. In the examination we have used the moisture % data of two growing sites, Debrecen and Szeged. The number of examined years was 3 in Debrecen, 4 in Szeged. At both growing sites, we have examined the moisture loss dynamics of hybrids with a fertilizer dose of 90 kg N/ha.

We have proved that the rate of moisture loss is primarily influenced by temperature from the environmental parameters. The length of phase (the time of black layer formation) is determined by the distribution of precipitation and the characteristics of the hybrid. The dynamics of moisture loss for a specific genotype in the function of heat sums can be approached with a common regression line, the specific years did not differ significantly from each other. Particular hybrids react more sensitively to different environmental factors, the dynamics of moisture loss changes from year to year, so it cannot be characterised with a regression line.

In the examination of **physical moisture loss phase** we have used the data of those years and samples, where at least 3 samples takings were carried out after the physiological ripening:

- Debrecen: MV 484 SC, DB 377 SC and DK 471 SC year of 1997
- Szeged: AW 043 SC, Clarica SC, Clarisia SC, Evelina SC, Goldaris SC and Monessa SC from the years 1996-1998.

The examinations have proved, that physical moisture loss – beside temperature – is determined precipitation (humidity). The correlation can be well characterised with linear lines, the R-squares showed close conformity in all cases.

We have examined the effect of fertilization from all the agrotechnical factors effecting **yield elements** and **moisture content of maize**. We have included the data of DK 471 SC and MV 484 SC from the years of 1998 and 1999. We have examined the effect of nutrient supply in 1998 by using a control and five-, while in 1999 a control and three (90 kg N/ha, and 150 kg N/ha) fertilizer treatments.

The effect of fertilization was approached with a quadratic function. The **number of grains** increased significantly, due to the effect of fertilization, compared to the control parcels verifying, that nutrient supply (with given water supply) favourably influences pollination and yield.

Calculating potential evaporation and water supply

The potential evaporation was calculated on the basis of SZÁSZ's (1988) method:

$$PE= \alpha * [0.0054(T+21)^2(1-R)^2/3Ά(f_{(v)})]$$

where
- α = factor of the oasis-effect
- T = daily average temperature(^{O}C)
- R = saturation fraction
- $f_{(v)}$ = windspeed function (m/s)

In order to characterize the climatic conditions of specific years, we have calculated the water supply indexes for decades (SZÁSZ, 1988):

$$VE= CS +10/PE$$

where
- CS = daily precipitation (mm)
- PE = potential evaporation (mm)

2.3. Evaluating weather data for production sites

Debrecen

In 1994, the total amount of precipitation was 380 mm and 151 mm fell during the growing season. In the period between the gathering of forecrop and sowing the amount of precipitation was 314 mm. In this period, precipitation was optimal compared to the average of many years (288 mm). In the critical period of July-August a total of 46 mm of precipitation fell. In 1994, the average annual temperature was 11,0 ^{o}C, which differed by 1,0 ^{o}C-al from the average of 50 years.

In 1995-ben 495 mm precipitation fell, which is 88 mm less than the 50 year average. In the period between the gathering of forecrop and sowing of maize 189 mm precipitation fell, which is 99 mm less than the average of many years (288 mm). During growing season (end of April-end of October) 235,3 mm precipitation fell. This amount is a deviation from the optimal level, 101,7 mm less than the average of many years (337 mm). In the critical period, in the month of July 3,3 mm of rain fell, while in August 97,2 mm fell.

In 1996, until the end of September 475 mm of precipitation fell, which is 37 mm more than the average of 50 years. During the period lasting from the gathering of forecrop until the sowing of maize 189 mm of rain fell, which is 99 mm less than the average of many years (288 mm). During growing season (end of April – end of September) 400 mm precipitation fell. This amount exceeds the average of many years (295 mm) by 105 mm. In the critical period of July 25 mm, in August 84 mm fell.

In 1997, a total of 394.7 mm precipitation fell, 188.3 mm less than the average of many years. During the period between the harvest of forecrop and sowing 113 mm precipitation was measured, which is well below the 50 year average (243 mm). Following the really dry winter term, the amount of water stored in the soil (primarily in the upper 5-10 cm layer) significantly setback the germination and emergence of maize. Following emergence, the lack of precipitation was moderate and the distribution of it was also favorable especially in the critical period of July and August.

In 1998, during the winter term 157 mm precipitation fell, which is 86 mm less than the average of many years. However, during growing season (first decade of May – first decade of October) 470.9 mm fell, exceeding the the 50 year average by 130.9 mm. Precipitation that fell during this period and the amount of water stored soil resulted an optimal water supply. The development of plant stock was still favorable without irrigation, due to the abundant precipitation, that well exceeded the usual amount, a record amount of yield was harvested. During the month of July, which is often deficient in precipitation, 88.2 while in August 39.2 mm of rain fell. The total amount of precipitation of the two months slightly exceeded the value calculated on the basis of 50 year averages (121 mm).

The year of 1999, similarly to 1998 had more precipitation than the average of many years. During the year 635.4 mm precipitation fell, 389.2 occured during the growing season.

This value exceeded the average of many years by 49.2 mm. Precipitation of the summer months resulted in a favorable water supply. In July and August, a total of 106.9 mm precipitation fell, which is slightly less than the average of many years.

In order to characterize the examined years, we have calculated potential evaporation (PE) and water supply. Upon comparing the values of potential evaporation for the six year it can be noticed that the maximum of PE reached its annual maximum in July and not in June in 1996.

In 1994, during growing season beginning from the first decade of June until the second decade of August water supply was at low values. Especially the end of June, the second and third decade of July was very dry.

In 1995, the values of water supply were higher than in the previous year, but in the critical period of flowering significant drought occured, which significantly hampered fertilization.

In 1996, the precipitation of the growing season was favorable but its distribution was not even. Significant portion of the precipitation (190 mm) fell in September, which is only partly utilized by maize. The water supply values fluctuated significantly, the first decade of July and August were especially dry.

3. RESULTS AND CONCLUSIONS

Previous research have proved, that determining **growing season** in days can only be done for a specific cultivation site and specific years. However, it does not provide reliable information for determining regularities and comparing different growing sites and years.

Growing season, primarily due to technical reasons (lack of daily temperature data), is expressed in days both in research and practise. Our examinations have proved that the relative deviation of growing season expressed in heat unit is smaller and has better reliability. When comparing vegetative and generative phases, it can be determined that the interval until flowering is more stable and the variation coefficient is smaller.

The **moisture loss dynamics of grain** were examined at two growing sites, in Debrecen and Szeged, in 90 kg N/ha fertilizer treatment. We have determined, which environmental parameters have dominant effects. According to the result of our examinations, primarily temperature influences the dynamics of moisture loss until the formation of black layer.

We have considered it important to pick apart the period of moisture loss to typical phases, in order to examine grain development and decrease of moisture content more accurately.

It was an important aspect to identify the beginning and end of specific periods and to approximate the specific intervals with a linear line.

On the basis of our examinations – similarly to reference data – the generative phase, from the aspect of moisture loss was divided into three periods:

- the period ranging to water maximum
- the period ranging from water maximum to the form of black layer
- period of physical moisture loss

The period ranging to **water maximum** was examined on the basis of data obtained in 1997 and 1998 on the growing site at Debrecen, because we have taken samples in both years from the beginning of grain development until the formation of black layer. We have used the data of maize hybrids DB 351 SC, DB 377 SC, DK 471 SC, MV 484 SC and Occitan SC.

We have determined, that the values of water maximum vary according to hybrids and years. In a specific year, there are no significant differences in the effective heat sums belonging to maximum values, the difference is 2-4 calendar days.

In Debrecen, we have examined the effect of fertilization on the grain yield of maize, at six levels – without fertilization and with five fertilizer doses – on yield data obtained in Debrecen. The fertilizer doses 1N: 0.75 P_2O_5: 0.88 K_2O constant ratio NPK doses, where the basic dose was 158 kg until 1995, from 1996 it was 89 kg/ha. Since NPK ratio is constant ratio, we will mark doses with the amount of nitrogen active agent for the sake of simplicity. The examined years were between 1994-1999. Those hybrids were included in the evaluation, that had at least three years of yield data.

Still in Debrecen, we have examined the effect of fertilization on grain filling, number of grains and dynamics of moisture loss in the generative phase, in 1998 and 1999.

2.4. Method of evaluation

We applied a linear model and regression analysis commonly used to examine the dynamics of moisture loss. With the help of the generally used linear model (GLM), we can use the statistical hypothesis regarding the significant differences between the groups of variables and we can set up mixed models for evaluating both the permanent and random effects. The GLM is a flexible statistical tool for analysing normal distribution target variables and for analysing correlation between independent variables. We refer to persistent variables as covariates in the method. The statistical analysis of the GLM model was complemented with a linear regression analysis. In order to determine the accuracy of multiple R-value fittings, we have considered the standard errors and the confidence intervals of specific subgroups.

The effect of fertilization on grain filling, moisture loss and grain number was evaluated with one factorial variance analysis, on the basis of SVÁB's (1981) methodological book.

The yield increasing effect of fertilization was examined with a quadratic regression function. During the analysis we have also calculated a coefficient, which is a parameter that can be used to reliably characterize natural nutrient utilization. The correctness of the fitting was checked multiple R-values as well as with variance analysis of the regression, F-probe and by considering the standard error of estimating. The parameters of the equation were tested with t-probe and to judge the significance we have used a symmetrical test. The differences between treatment averages were checked with a Duncan test. We have used the Duncan grade test to examine the common homogeneity of treatment subgroups (HUZSVAI 2000).

By using this test we can identify those treatment combinations, which belong to one homogeneous group, and the significant differences can be easily separated.

The statistical evaluations were done with the help of SPSS for Windows 9.0 and Excel XP softwares.

Starting from 1997, favorable years followed. The water supply of the year "97 was good, a droughty period occured in the critical period.

The years of 1998. and 1999. were favorable for maize. Water supply was even throughout the whole growing season, flowering and during the first phase of grain filling the amount of precipitation was optimal.

Szeged

1996. was a favorable year for maize production. 376 mm of precipitation fell in the growing season. The water supply of the critical periods was appropriate, the second decade of July was poor in precipitation. The average temperature of the summer months matched the fifty year average, the number of days with heat-wave was alltogether 5.

In 1997, the amount of precipitation during the growing season was alltogether 282 mm, but due to the favorable water supply of the critical perods the development and growth of maize was relatively unperturbed. The cold and wet May delayed sowing on the one hand and on the other hand it also delayed the development of the emerged stock. Due to the favorable climatic conditions of July, plants could develop optimally, only 2-3 days of delay was detected at flowering.

Examining the temperature data it can be established, that the lower and more stable average temparature also affected plants favorably.

1998 and 1999. were also similarly favorable years. The amount of precipitation was 382 mm in 1998, and 463 mm in 1999. In the period of emergence and flowering, precipitation was favorable, the development of plants in the early phases was nearly optimal. The weather characteristics formed according to the years with more precipitation, there were no extended heat waves.

In order to characterize the examined years, we have calculated potential evaporation (PE) and water supply. The values of potential evaporation regarding the six years formed according to Debrecen.

The precipitation supply of the growing season was favorable in 1996, but its distribution was not even. The water supply values fluctuated significantly, the first decade of July was a specifically dry period.

The water supply of 1997 was good. No significant periods occured with poor precipitation, the water supply of May and July was specifically even.

The years of 1998. and 1999. were favorable for maize. Water supply was even during the entire growing season, flowering and in the early phases of grain filling when the amount of precipitation was optimal.

2.5. Method of sampling

We have determined the time of emergence and 50% flowering in the vegetative phase. We have also determined the time of black layer formation according to hybrids and treatments in the generative phase.

In Debrecen, following flowering destructive samplings wer - in 1998 and 1999, while in 1997 these operations were carried out every 3 days on average. (table 4.).

Table 4. Time of samplings *(Debrecen, 1997-1999)*

Time of samplings	1997	1998	1999
1.	August.13.	July. 25.	July. 25.
2.	August.15.	August.06.	August.16.
3.	August.18.	August.28.	August.27.
4.	August.22.	September.02.	September.02.
5.	August.25.	September.11.	September.10.
6.	August.27.	September.25.	September.16.
7.	August.29.	October.15.	September.24.
8.	September.01.		September.30.
9.	September.03.		October.07.
10.	September.05.		October.15.
11.	September.08.		
12.	September.10.		
13	September.12.		
14	September.15.		
15	September.17.		
16	September.19.		
17	September.22.		
18	September.24.		
19	September.29.		
20	October.01.		
21	October.03.		
22	October.06.		

At times of samplings, we have measured the weight of 50 grains taken from the midsection of 4 maize cobs in 4 repetitions, in Debrecen. Determining dry matter content was carried out by using a dryer box at 60 ^{0}C, and drying was performed until reaching stable weight.

Samplings at Szeged were carried out once a week, beginning from the end of August (table 5.). 3 cobs were used as one sample per repetition in Szeged, and the weighed raw grain – by gradually increasing the temperature – was dried until reaching stable weight at 105 ^{O}C maximum.

The moisture loss dynamics of hybrids was evaluated in 90 kg N/ha fertilizer treatments at both production sites.

Table 5. Times of samplings *(Szeged, 1996-1999)*

Samplings	1996	1997	1998	1999
1.	08.26.	08.25.	08.26.	08.26.
2.	09.02.	09.01.	09.03.	09.03.
3.	09.09.	09.09.	09.08.	09.09.
4.	09.16.	09.15.	09.14.	09.15.
5.	09.23.	09.23.	09.23.	09.22.
6.	10.01.	10.01.	10.01.	09.29.
7.	10.07.	10.09.	10.07.	10.05.
8.	10.22.	10.16.	10.12.	

I have included the following maize hybrids in the evaluation:

Name of hybrid	FAO number	Number of examined years
MONESSA	270	3
KANADA	300	3
CLARICA	310	3
CLARISIA	310	3
SZE 277	320	4
DB 351	340	2
LG 2298	340	3
AW 043	380	4
DB 377	380	2
GOLDARIS	380	4
OCCITAN	380	6
DK 471	410	6
NASTIA	420	3
AW 143	450	5
MV 484	450	6
GOLDAFFE	460	4
VERONIKA	460	3
DK 527	490	3
FLORENCIA	530	3