UNIVERSITY OF DEBRECEN
CENTRE FOR AGRICULTURAL SCIENCES AND ENGINEERING
FACULTY OF AGRICULTURE
DEPARTMENT OF CROP SCIENCE

JENŐ HANKÓCZY DOCTORAL SCHOOL OF CROP PRODUCTION,
HORTICULTURAL AND FOOD SCIENCES

Head of Doctoral School:
Dr. Zoltán Győri
DSc.

Supervisor:
Dr. habil Mihály Sárvári
associate professor

„THESES OF DOCTORAL (PhD) DISSERTATION"

Examination of the relation between NPK fertilization, yield quantity and quality of maize hybrids with different genetic characteristics

By:
Nóra El Hallof

Debrecen
2008

1. Introduction, prelude of research

Cereal production is the major branch of the world's crop production, cereals are grown on approximately half of the total arable area. A similar trend can be observed in Hungary, where wheat and maize are the most important crops, their growing area constitutes about 50% of the total arable land of 4.5 million hectares, out of which the growing area of maize have been around 1-1.2 million hectares for several decades.

Regarding the yield, three eras can be differentiated in the history of maize production in Hungary. From 1921 until 1980, maize yield increased linearly and from the 1980s until the change of the regime, it reached, then exceeded 6 t/ha. This significant development was due to the increased use of chemicals, improvement of the technology, modern hybrid use and last but not least the breeding and research work performed at the Hungarian research bases. Nowadays, the yields are not so favourable, the yield fluctuation can reach even 30-50%. In the dry year of 2003, the national average yield was 3.99 t/ha, while in the period of 2004-2006, yields of 7-7.7 t/ha were achieved due to the favourable climate conditions.

There have been significant changes in the utilization of maize also. In the last years, its utilization for animal feeding has reduced and the industrial use, especially as a basic material for bioethanol production, has increased. In the past years, the possibility of intervention created a certain market for the growers, but the intervention purchase by the Union was stopped and bioethanol production did not fulfill the hopes. The changes in the utilization of maize modify the quality and inner content requirements also. As a feedingstuff, high protein content is required, while for industrial use high carbohydrate content should be targeted.

The market position of maize has to be improved in the future and in order to maintain the competitiveness of the industry, maize production has to be stabilized, the annual yield fluctuation has to be mitigated and yield safety has to be increased. Primarily, the elements of hybrid-specific production technology should be considered, so the continuously increasing hybrid assortment calls for a continuous study of the hybrid-agrotechnique-environment interactions in crop production.

From these three factors, presently only the biological bases meet the most recent requirements, the available hybrids have an excellent genetic background, their yielding capacity, water-releasing and water- and nutrient utilization abilities, resistance and tolerance to stress factors are continuously improving. In the past years, the changes in

variety use accelerated and numerous foreign breeding companies appeared in the Hungarian market in addition to the modern hybrids from Martonvásár and Szeged.

The agrotechnical factors do not satisfy the requirements of maize in many cases, among others, neither the quantity nor the quality of fertilization is appropriate, 70% of the applied 90-100 kg/ha fertilizers applied is nitrogen, phosphorus and potassium supply do not have an appropriate weight, which weakens the drought tolerance, disease resistance and yield safety of hybrids and reduces soil fertility. Arising from the different genetic backgrounds, the hybrids differ in their natural nutrient utilization and fertilizer response. Under favourable ecological conditions, maize utilizes well the available nutrients of the soil, but for achieving high yields, fertilization is needed.

Among the ecological factors, the climate conditions were very unfavourable in the last years, the frequency of dry years has increased. The negative effects of the weather extremes can only be mitigated by selecting hybrids adapting to the growing site and by applying a hybrid-specific production technology.

For sustainable crop production, environmental awareness should be strengthened, the effect of each agrotechnical measure on the yield (quality and quantity) and the environment should be considered.

2. Research objectives

I carried out my research in a maize fertilization experiment set up at the Demonstration Garden of the University of Debrecen Centre for Agricultural Sciences and Engineering, Institute of Plant Sciences in 2004, 2005 and 2006. In the experiment, I studied the yielding capacity, natural nutrient uptake and utilization, water release dynamics and grain moisture content at harvest for ten maize hybrids with different genetic qualities and vegetation periods at five fertilization levels. During the three years, the effect of NPK fertilization on the photosynthetic activity, leaf area index and starch, raw protein and raw oil content of hybrids was evaluated. The experiment was set up in three repetitions (in addition to the control without fertilization) in a randomized block design.

3. Materials and methods

3.1. Maize hybrids involved in the experiment

In the experiment, I have tested 10 hybrids with different genetic characteristics and vegetation periods. The Hungarian and foreign hybrids were selected from the very early, early, medium and medium-late maturity groups: PR39D81 (FAO 280), DK 440

(FAO 320), PR37M34 (FAO 360), DK 4626 (FAO 370), PR38A24 (FAO 380), Mv Maraton (FAO 450), Sze SC 463 R (FAO 450), DKC 5211 (FAO 460), PR36R10 (FAO 490), Mv Vilma (FAO 510).

3.2. Weather of the experimental years

3.2.1. Weather of 2004

Based on the yearly data, it can be stated that 2004 was the most rainy among the three experimental years. The amount of precipitation was higher by 143.3 mm than the average (565.3 mm) of 30 years (1961-1990). In 2004, the amount of precipitation in the vegetation period of maize (1 April–30 September) was 422 mm which was 76.9 mm higher than the average of 30 years (345.1 mm), but its distribution was unfavourable. This is illustrated by the fact that in July, 105.9 mm rain fell in 4 days from the total precipitation of 154.8 mm, while in August 72.5 mm rain out of the total 74.8 mm fell in four days again in the second half of the month. The drier September promoted the water release of maize in the ripening period. The monthly mean temperatures during the year and the vegetation period of maize were around the average of 30 years (*Table 1*).

3.2.2. Weather of 2005

Similarly to the previous year, 2005 was a rainy year, and the more rainy months were mostly during the vegetation period of maize. In the vegetation period of maize, the amount of precipitation was 497.3 mm, which was 152.2 mm higher than the average of 30 years (345.1 mm), while the annual precipitation was 80.5 mm higher. April and August were more rainy than the average, the amount of precipitation was 53.6 mm higher and more than twice higher (135.1 mm), respectively, than the average of 30 years (60.7 mm), which resulted in a delay of sowing and prolongation of the maturity period. The uneven distribution of precipitation could be observed in this year also, out of the 52 mm precipitation in June, 50.5 mm fell in two days, while from the total of 135.1 mm in August, 99 m fell in four days. The mean temperature – except for February and March – followed the pattern of the thirty-year average, in February and March, it was 3.9^{o}C and 2.8^{o}C lower, respectively, but it did not have an effect on the emergence of maize.

1. table: **The fluctuation of precipitation and temperature (Debrecen, 2004-2006)**

Month	Quantity of precipitation (mm)				Average temperature (°C)			
	2004	**2005**	**2006**	***30 year average***	**2004**	**2005**	**2006**	***30 year average***
January	46.7	5.0	26.5	*37.0*	-3.3	-0.9	-3.4	*-2.6*
February	49.6	40.5	67.7	*30.2*	-0.7	-3.7	-1.4	*0.2*
March	58.3	12.0	65	*33.5*	4.8	2.2	3.2	*5.0*
April	41.6	96.0	92.5	*42.4*	11.4	10.8	12.1	*10.7*
May	20.3	59.2	66.7	*58.8*	14.8	16.2	15.4	*15.8*
June	93.4	52.0	71.6	*79.5*	19.3	18.4	18.6	*18.7*
July	154.8	89.5	34.9	*65.7*	21.1	21.1	23.2	*20.3*
August	74.8	135.1	75.7	*60.7*	20.4	19.7	19.0	*19.6*
September	37.1	65.5	6.0	*38.0*	15.3	16.5	17.0	*15.8*
October	36.0	12.0	26.3	*30.8*	11.1	10.8	11.3	*10.3*
November	70.0	16.0	9.0	*45.2*	4.9	3.5	6.2	*4.5*
December	26.0	63.0	11.7	*43.5*	0.9	0.2	2.2	*-0.2*
Sum-total Average	***708.6***	***645.8***	***553.6***	***565.3***	***10.0***	***9.57***	***10.28***	***9.84***
Differences from 30 year average	**143.3**	**80.5**	**-11.7**	**-**	**0.16**	**-0.27**	**0.44**	**-**
Breeding season (April–Sept.)	**422**	**497.3**	**347.7**	**345.1**	**17.06**	**17.1**	**17.56**	**16.82**
Differences from 30 year average (April–Sept.)	**76.9**	**152.2**	**2.6**	**-**	**0.24**	**0.28**	**0.74**	**-**

3.2.3. Weather of 2006

2006 was disadvantageous for the growth and development of maize in several aspects. The amount of precipitation in the vegetation period of maize was only 2.3 mm higher (347.4 mm) than the average of 30 years. In July, in a critical period for maize, the amount of precipitation was 30.8 mm lower than the average of 30 years. The above average temperature in July (23.2°C) coupled with the water deficiency was disadvantageous for the blooming and fertilization of maize. In addition, as a result of the increasingly frequent extreme meteorological phenomena, a heavy hail and windstorm damaged the plants in July. In the period of maturing, the water release processes were assisted by the prolonged dry and warm weather in September.

3.3. Soil of the experimental area

The soil of the experimental area was calcareous chernozem. The top layer was deficient in lime, consequently, it was prone to cracking under dry weather conditions. The nutrient content of the soil was of medium level, with good nutrient dynamics, the soil could be cultivated easily due to its crumb structure. The thickness of humus in the

A layer was 50-70 cm, the organic matter content was 2.57%. The plasticity index according to Arany was 45, the pH value was 7.0 (H_2O). The N content of the soil was 0.12%, while the Al-soluble P_2O_5 content was 100 mg/kg and the K_2O content was 165 mg/kg.

3.4. Agrotechniques applied in the experiment

In all three years of the experiment (2004-2006), five different fertilizer dosages were applied in addition to the control treatment (without fertilization). The smallest fertilizer dosage per hectare was N 40, P_2O_5 25 and K_2O 30 kg active ingredient. The largest dosage was five times higher, N 200, P_2O_5 125, K_2O 150 kg/ha active ingredient (*Table 2*).

2. table: **The applied fertilizer doses in the experiment (2004-2006)**

Treatment	**N** (kg/ha)	**P_2O_5** (kg/ha)	**K_2O** (kg/ha)	**Sum total active agent** (kg/ha)
Control	-	-	-	**-**
1. treatment	*40*	*25*	*30*	***95***
2. treatment	*80*	*50*	*60*	***190***
3. treatment	*120*	*75*	*90*	***285***
4. treatment	*160*	*100*	*120*	***380***
5. treatment	*200*	*125*	*150*	***475***

The forecrop was maize monoculture in each year. The basic cultivation was autumn ploughing in all years, followed by surface levelling and seedbed preparation in the spring. Sowing was performed at the end of April in all three years with a hand seeder. The crop protection operations were weed control and soil disinfection (*Table 3).*

3. table: **Data of agrotechnics (2004–2006)**

	2004	**2005**	**2006**
Soil preparation Plough in autumn Prepare of seed-bed	7 Nov. 2003 15 April	17 Nov. 2004 15 April	20 Nov. 2005 18 April
Sowing date	19-20 April	30 April-1 May	24 April
Plant density	very early, early maturing hybrids 71 thousand plant/ha medium, mid-late maturing hybrids 65 thousand plant/ha		
Emergence date	1-2 May	10-12 May	2-3 May
Weed control	30 April 3 June 5-9 July	31 May 18-21 July	29 May
Harvest	16-17 October	12 October	12 October

3.5. Other examinations

Photosynthetic activity was measured with a portable Licor 6400 photosynthesis measuring instrument, while leaf area was measured with a Licor 2000 leaf area measurer. The measurements were performed four times a year at the same dates.

The measurements of protein, starch and oil content were performed by the colleagues of Dr. Zoltán Győri at the Institute for Food Sciences, Quality Assurance and Microbiology, UD Centre for Agricultural Sciences and Engineering. Starch content was determined according to the standard MSZ 6830/18-1988, protein content was determined by destruction method, oil content was measured with a semi-automatic Soxtec equipment.

4. Results, main statement of dissertation

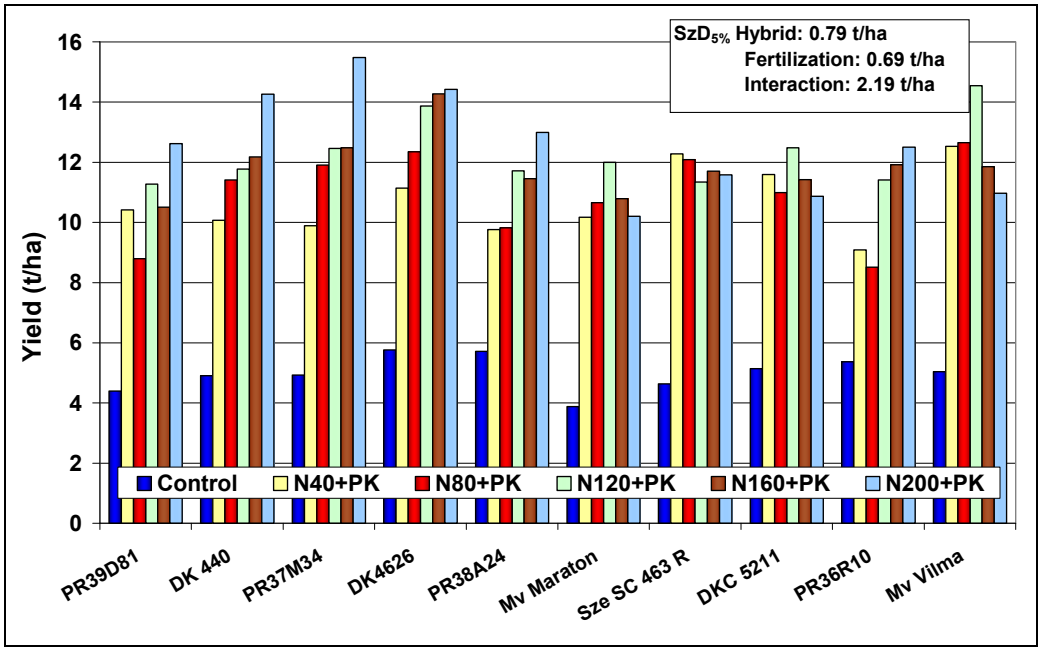
4.1. The effect of fertilization on the yield of maize hybrids

In 2004, the yield of hybrids without fertilization ranged between 3.88 and 5.76 t/ha. Among the fertilization treatments, the first treatment of N40, P25, K 30 kg/ha (hereinafter N40+PK) resulted in the largest yield increment, 5.71 t/ha, from the other treatments only the treatment of N120, P75, K90 kg/ha (hereinafter N120+PK) with 1.37 t/ha and the treatment of N200, P125, K150 kg/ha (hereinafter N200+PK) with 0.73 t/ha resulted in a significant yield increment. The maximum yield of hybrids ranged between 12.0 and 15.48 t/ha which were achieved at the fertilizer dosages N40+PK, N120+PK and N200+PK (*Figure 1*), but the fertilizer dosages belonging to the maximum yield can be reduced by even 20-44 kg/ha N+PK without a significant reduction of the yield.

The yield of the hybrids in the average of the fertilizer treatments ranged between 9.62-11.97 t/ha, with the lowest yield for *Mv Maraton* (9.62 t/ha) and the highest yield for *DK 4626* with 11.97 t/ha. Hybrids with yields above the average (10.55 t/ha) were *DK 440* (10.77 t/ha), *PR37M34* (11.19 t/ha), *DK 4626* (11.97 t/ha), *Sze SC 463 R* (10.6 t/ha) and *Mv Vilma* (11.27 t/ha).

The most intensive yield increment was obtained for *DK 4626* among the FAO 200-300 hybrids and for*, Mv Vilma* among the FAO 400-500 hybrids. On the contrary, the yield of the hybrids *PR39D81*, *PR38A24* and *PR36R10* increased only slightly with the increasing fertilizer dosages.

1. figure: **Effect of fertilization on the yield of maize hybrids (Debrecen, 2004)**



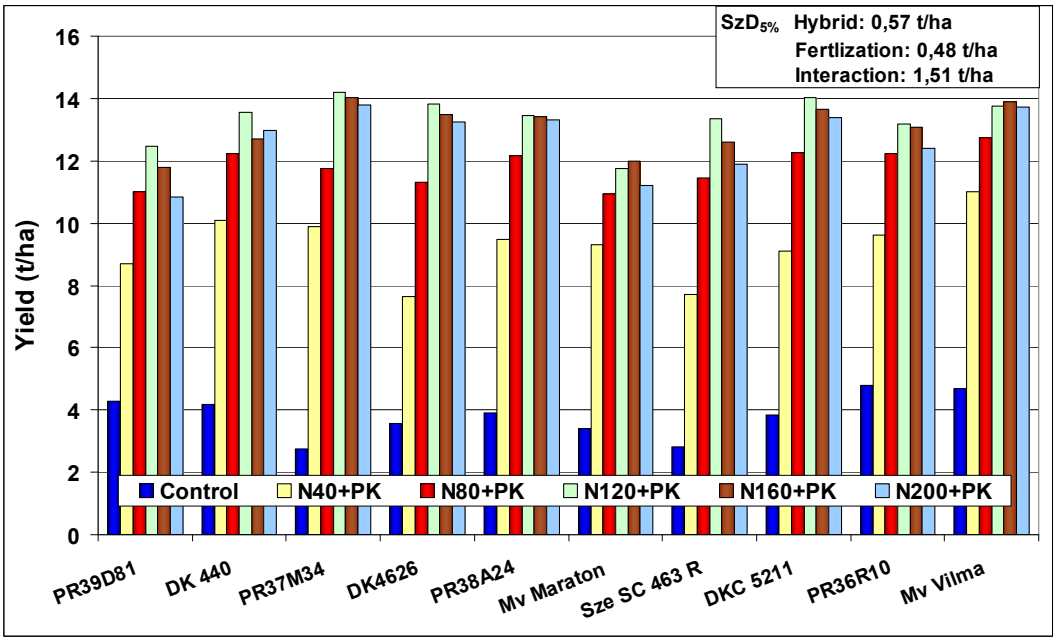
In 2005, the average yield of the hybrids without fertilization was lower than that of the previous years, ranging between 2.75-4.77 t/ha. In the average of hybrids, fertilization up to the N120+PK level increased the yields significantly (with decreasing increments), the lowest fertilizer dosage increased the yield with 5.44 t/ha as compared to the control, the treatment of N80, P50, K60 kg/ha (hereinafter N80+PK) augmented the yield with 2.55 t/ha as compared to the previous fertilizer level and N120+PK resulted in a 1.55 t/ha yield increment. A further increase of the fertilizer level, however, resulted in a yield depression in all hybrids as shown in *Figure 2*.

The studied hybrids – except for the hybrids from Martonvásár- reached their maximum yield at the dosage N120+PK (12.45-14.21 t/ha), the yield of the hybrids *Mv Maraton* and *Mv Vilma* increased up to the treatment N160, P100, K120 kg/ha (hereinafter N160+PK). The highest yield was obtained for *PR37M34* with 14.21 t/ha, but *DKC 5211* with a longer vegetation period also achieved 14.03 t/ha. The yield of the hybrids in the average of the fertilizer treatments varied between 9.77-11.63 t/ha, the hybrids *PR37M34* (11.07 t/ha), *DK 5211* (11.05 t/ha), and *Mv Vilma* (11.63 t/ha) had outstanding results in this year also.

For this experimental year, it can be stated also that the fertilizer dosage belonging to the maximum yield can be reduced by 20-24 kg/ha N+PK without resulting in a yield reduction larger than half of the $SD_{5\%}$ value. Among the FAO 200-300 hybrids, *PR37M34* responded with a very intensive yield increment to the increasing fertilizer

dosages, based on its yield in the control plot (2.75 t/ha), it can be stated that its natural nutrient utilization ability is weak, but it has an excellent fertilizer response. Among the hybrids with a longer vegetation period, *Sze SC 463 R* gave an intensive yield increment to increasing fertilization, its yield was 10.54 t/ha higher than in the treatment without fertilization.

2. figure: **Effect of fertilization on the yield of maize hybrids (Debrecen, 2005)**

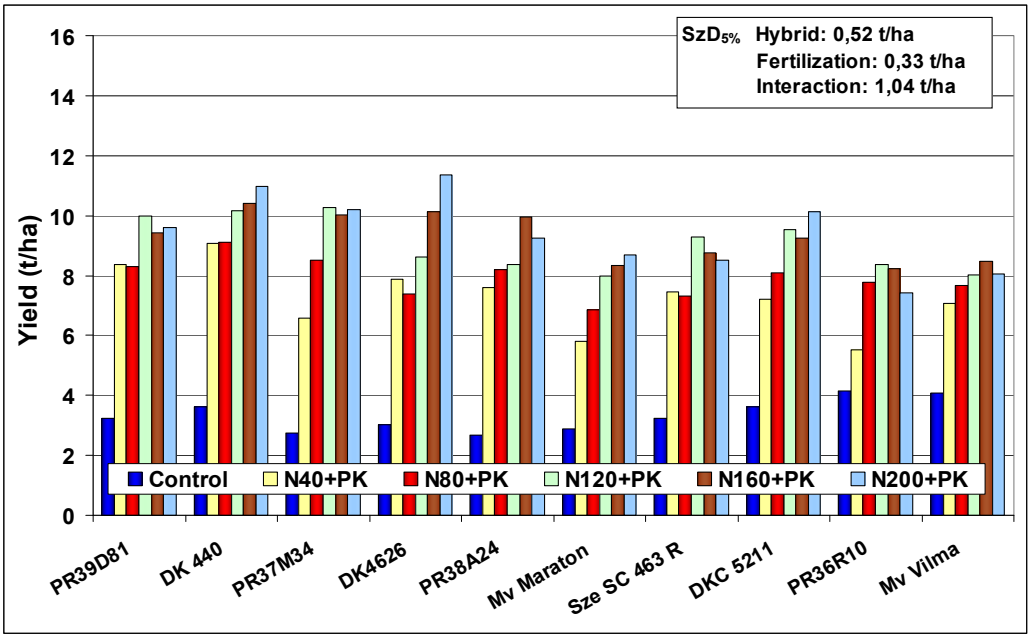


The yield of the hybrids was considerably lower than in 2004 and 2005, this was due to the year effect. In 2006, the dry weather was accompanied with a high temperature in the critical period of maize, which damaged the flowering, fertilization and grain-filling processes and this had the strongest effect on the hybrids with the longest vegetation periods. The yields in the control treatment ranged between 2.67-4.14 t/ha, similarly to the previous two years, the hybrids *PR36R10* and *Mv Vilma* achieved the highest yields without fertilization 4.14 and 4.07 t/ha, respectively. The maximum yields of the hybrids varied between 8.35 and 11.35 t/ha, the yield increments had a decreasing trend in the average of the hybrids, it was 3.92; 0.67; 1.13; 0.25 and 0.11 t/ha for the different fertilizer levels, but the treatments N160+PK and N200+PK did not increase the yields significantly. In the average of the fertilizer treatments, the FAO 200-300 hybrids, *PR39D81*, *DK 440*, *PR37M34* and *DK 4626* achieved higher yields ranging between 8.06 and 8.89 t/ha, since the heat and drought stress in the summer had a weaker effect on their flowering and fertilization processes. From the hybrids with a longer vegetation

period, only *DKC 5211* achieved a higher yield with 7.98 t/ha, the yields of the other hybrids varied between 6.76 and 7.43 t/ha only (*Figure 3*).

In 2006, the lower limit of the optimal nutrient level of the maize hybrids was between N116+PK and N192+PK, which was 8-28 kg/ha lower than the dosage belonging to the maximum yield. In this year, not only the yields were lower than those in 2004-2005, but the fertilizer response of the hybrids was also weaker. The higher dosages of fertilization resulted in a yield reduction, the most intensive fertilizer response was obtained for the hybrids *PR37M34* and *Sze Sc 463 R*.

3. figure: **Effect of fertilization on the yield of maize hybrids (Debrecen, 2006)**



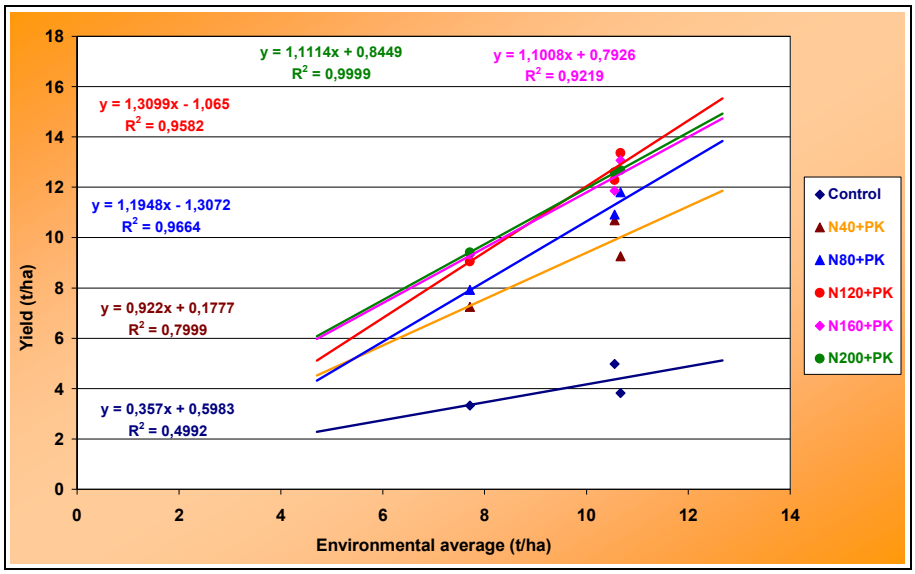
4.2. The effect of fertilization on the yield stability of maize hybrids

For the period of 2004-2006, I studied the effect of the different fertilizer treatments on the yield stability of maize in the average of the hybrids and in the average of three years.

The most stable but lowest yield (3.3-5 t/ha) was obtained in the treatment without fertilization. Due to the rainy year, even the lowest fertilizer dosage resulted in a considerably high yield increment, the greatest change was observed in the yields of treatments N80+PK and N120+PK under improving environmental conditions, but the yield belonging to the N120+PK dosage was always higher than that of N80+PK (*Figure 4*). At higher than 10 t/ha environmental average, the N120+PK treatment exceeded the yield of the control treatment (3.3-3.8 t/ha) by 7.3-9.5 t/ha. In the N160+PK and N200+PK treatments the yield was 9.3-9.4 t/ha under the environmental

conditions of 7.7 t/ha which was higher than that of the other treatments, however, their yields above 10.5 t/ha environmental average (12.7-13.1 t/ha) was lower than that of the optimal N120+PK dosage (13.4 t/ha).

4. figure: **Effect of fertilization on the yield stability of maize hybrids (Debrecen, 2004-2006)**



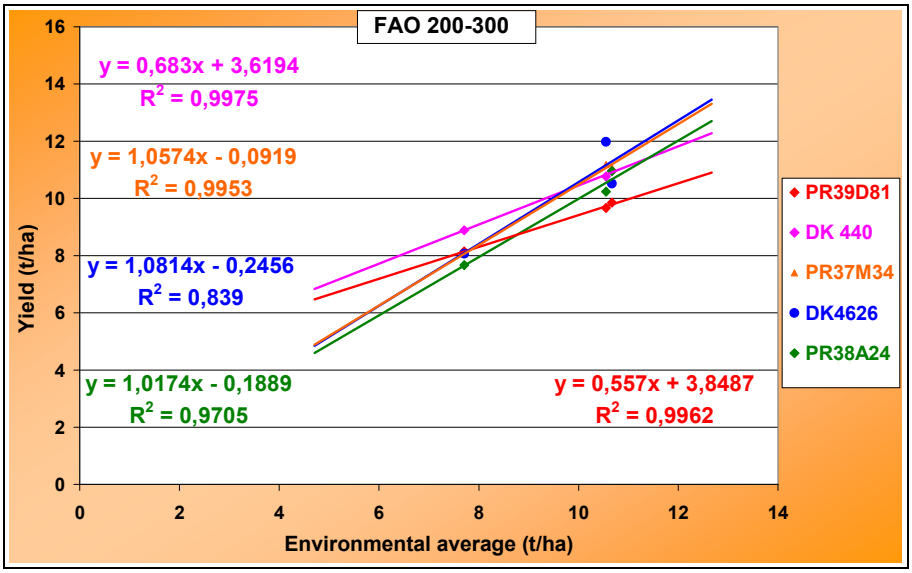
The yield stability of the hybrids was studied also in the average of the fertilizer treatments. Among the FAO 200-300 hybrids, the yields of *DK 440* and *PR39D81* were higher (8.2-8.9 t/ha) than the yield of the other hybrids (7.7-8.1 t/ha) under weaker environmental conditions of 7.7 t/ha. With the further improvement of the environmental conditions, the yield of the hybrids *PR37M34* and *DK 4626* increased with the largest extent at almost the same rate, under an environmental average of 10.5 t/ha, they had maximum yields of 11.2-12.0 t/ha, which were higher than those of the other three hybrids. The hybrids *DK 440* and *PR39D81* had the most stable yields in this group (*Figure 5*).

Among the FAO 400-500 hybrids, the yields of *DKC 5211* and *Sze SC 463 R* increased almost simultaneously with the environmental average and under the environmental conditions of 7.7 t/ha, their yields were higher than those of *Mv Maraton*, *PR36R10* and *Mv Vilma* by 0.6-1.2 t/ha (*Figure 6*).

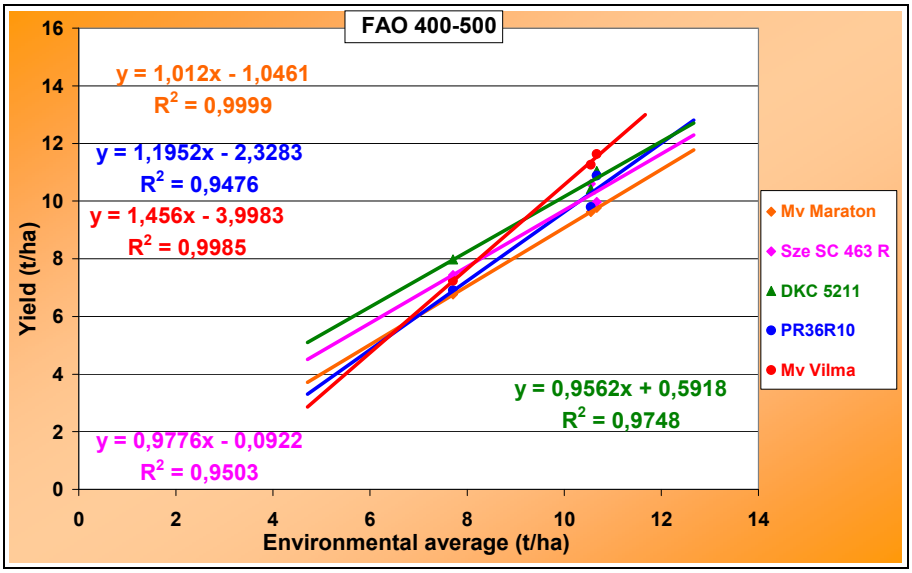
The hybrid *Mv Vilma* with the longest vegetation period responded most intensively to the improvement of the environmental conditions, its yield was the lowest under the environmental average of 7 t/ha, but above 10.5 t/ha, its yield was higher than that of the other hybrids in the same maturity group, its yield increased by 4.1 t/ha. Among the

hybrids with longer vegetation period, the yield of *DKC 5211* proved to be the most stable in the average of the three years.

5. figure: **Effect of fertilization on the yield stability of maize hybrids with FAO 200-300 (Debrecen, 2004-2006)**



6. figure: **Effect of fertilization on the yield stability of maize hybrids with FAO 400-500 (Debrecen, 2004-2006))**



Based on the results of the three years, it can be concluded that year, and the amount of precipitation within this, has a determining role in nutrient uptake and via this in yield formation. In wet years, the maize hybrids utilized well the natural nutrient stock of the soil and the applied fertilizers. In favourable years, the specific fertilizer response and fertilizer requirement of the hybrids with different genetic characteristics were more

definite, while in unfavourable years, the adaptability of the hybrids was of greater importance.

4.3. The effect of fertilization on the water release dynamics of maize hybrids and grain moisture content at harvest

The water release of six hybrids with different genetic characteristics and vegetation periods was measured at the fertilizer levels of N120+PK and N200+PK at weekly intervals in the period between the formation of the black layer and harvest. The hybrids involved in the examinations were *PR39D81*, *DK 440*, *PR38A24*, *Sze Sc 463 R*, *DKC 5211* and *Mv Vilma*.

In 2004, the grain moisture content of the early hybrid *PR39D81* was the lowest with 18.23%, while *Mv Vilma* had the highest value with 24.03% in the average of the treatments. The grain moisture content of *DKC 5211* was favourable with the average value of 21.64%, which was 1.34% lower than that of *Sze SC 463 R* with a similar vegetation periods. In the average of treatments, there was a significant difference between the grain moisture content of the hybrids. When studying the effect of treatments in the average of hybrids, it can be concluded that the grain moisture content in the plots without fertilization and in the N200+PK treatment was higher than in the N120+PK treatment, but the difference was significant only between the N120+PK and the N200+PK treatments. The grain moisture content at harvest was 21.37%, 21.66%, and 20.59% in the control without fertilization, in the highest fertilization treatment and the N120+PK treatment, respectively.

In 2005, the grain moisture content was the lowest for the hybrid *PR39D81* with 15.56%, which was considerably lower than that of the others, the grain moisture content of *Mv Vilma* with the longest vegetation period was 10% higher than this, with 25.53%. The grain moisture content of the hybrids with the longest vegetation period was higher at harvest, but there were no significant differences among the hybrids *DK 440* and *PR38A24*, and *Sze Sc 463 R* and *DKC 5211*. In the average of hybrids, the treatments had no significant effect on the grain moisture content at harvest. We measured 20.19%, 21.03% and 20.98% in the N120+PK treatment, N200+PK treatment and in the control, respectively.

In the average of the treatments, the grain moisture content at harvest was the lowest in 2006. Based on the results, the hybrids with shorter vegetation period had a lower grain moisture content at harvest, the difference was even 5-10%. The hybrid *PR39D81* had the lowest grain moisture content, 10.4%, while *PR38A24* had the highest with

16.29%. The differences among the grain moisture content of the hybrids were significant, except for the difference between *Sze SC 463 R* and *Mv Vilma*. In this year, the grain moisture content of the hybrid *Mv Vilma* was lower than in the previous years 15.38% (*Table 4*). In the average of hybrids, there was a significant difference between the grain moisture content of the control (14.4%) and the N120+PK treatment (13.3%), but the difference between the control and the N200+PK treatment (13.81%) was not significant (*Table 5*).

4. table: **The seed moisture content (%) at harvest of maize hybrids in the average of treatments (Debrecen, 2004-2006)**

	2004	**2005**	**2006**
PR39D81 (FAO 280)	18,23	15,56	10,40
DK 440 (FAO 320)	19,67	19,58	11,60
PR38A24 (FAO 380)	20,67	20,16	16,29
SzeSC463R (FAO 450)	22,98	21,83	15,16
DKC 5211 (FAO 460)	21,64	21,76	14,20
Mv Vilma (FAO 510)	24,03	25,53	15,38
$SzD_{5\%}$	*0,87*	*0,8*	*0,57*

5. table: **Effect of different treatments on the seed moisture content (%) at harvest of maize hybrids in the average of treatments (Debrecen, 2004-2006)**

	2004	**2005**	**2006**
Control	21,37	20,98	14,40
N120 + PK	20,59	20,19	13,30
N200 + PK	21,66	21,03	13,81
$SzD_{5\%}$	*1,03*	*0,95*	*0,68*

In sum, it can be stated that the grain moisture content of the hybrids was influenced by the vegetation period, the level of fertilization and the year in addition to the water releasing capacity of the hybrid. The dynamics of water release is different in the period of maturity. The physiological maturing occurs earlier for the hybrids with quick water release and shorter vegetation period and their grain moisture content is below 35-40% already by the end of August and the beginning of September (e.g. *PR39D81, DK 440*). From physiological maturity until harvest, their daily water release was around 0.54-0.66 %, accordingly, their grain moisture content at harvest was between 10 and 20% depending upon the year. There are hybrids in which the dynamics of water release accelerates in the second half of maturing, e.g. *PR38A24*, *Sze SC 463R* and *Mv Vilma*.

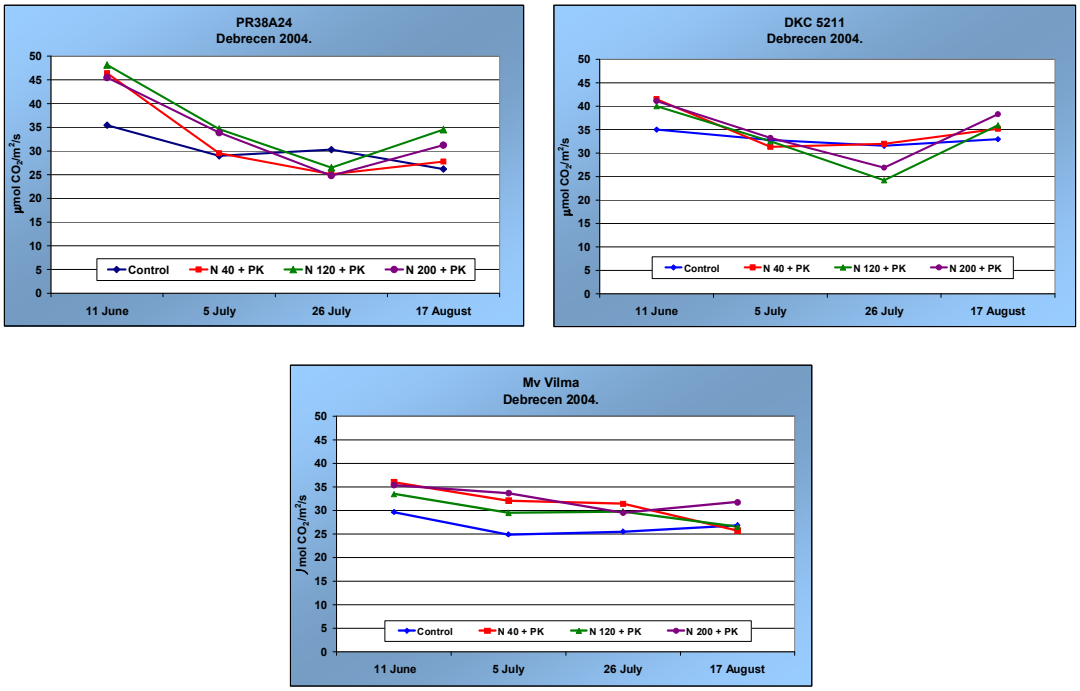
In the maturity period, the dynamics of water release was the more favourable in the treatment N 120, P_2O_5 75, K_2O 90 kg/ha as compared to the treatment N 200, P_2O_5 125, K_2O 150 kg/ha.

4.4. The relationship between fertilization and the photosynthetic activity of hybrids

In the experiment, the photosynthetic activity of five maize hybrids with different genetic characteristics was measured four times a year at different levels of nutrient supply (control, N40+PK, N120+PK, N200+PK).

In 2004, the measured photosynthesis values were the smallest in the control parcels with 29.4-34.3 µmol $CO_2/m^2/s$ in the average of the hybrids at the first, second and last measurement dates. Improving fertilizer levels increased the intensity of photosynthesis and significant differences were measured between the control and the N120+PK treatment in June (*Figure 7*).

7. figure: **Effect of nutrient supply on the photosynthetic activity of maize hybrids (Debrecen, 2004)**

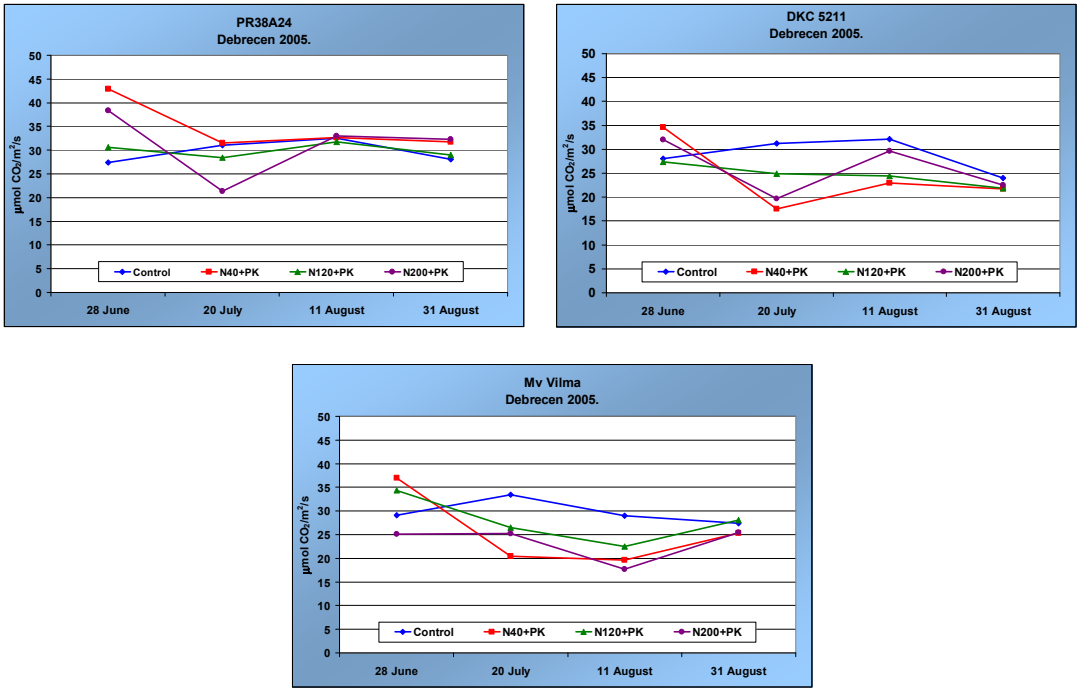


On the contrary, the photosynthesis was the highest in the control with 30.7 µmol $CO_2/m^2/s$ on 26 July, as a result of the fertilization, the intensity of net photosynthesis reduced to 28-28.9 µmol $CO_2/m^2/s$. The difference was probably due to the fact that the water requirement of maize increased as a result of the fertilization, a water deficiency occurred to which the plant responded with closing its stoma. This is proved by the low

values of transpiration and stoma permeability. Among the hybrids, *PR38A24* had the greatest photosynthesis ranging between 45.5 and 48.2 µmol $CO_2/m^2/s$ as a result of fertilization.

In 2005, the fertilization significantly increased photosynthesis at the first measurement (by 7 µmol $CO_2/m^2/s$), in the average of the hybrids. With the advancement of the season, fertilization did not increase photosynthetic activity, but the reduction was not significant. On 11 August, the photosynthetic activity was almost the same in the different treatments, 27.8-28.8 µmol $CO_2/m^2/s$. By the end of the vegetation period, photosynthesis was higher in the fertilized parcels, 26.5-28.4 µmol $CO_2/m^2/s$, than in the control (24.4 µmol $CO_2/m^2/s$), but the difference was not significant. The rainy weather in August resulted in a prolongation of the vegetation period, due to this, the photosynthetic activity reduced non-significantly at the optimum fertilizer level. Among the hybrids, *DK4626* and *PR38A24* had outstanding photosynthetic activity, exceeding 40 µmol $CO_2/m^2/s$ (*Figure 8*).

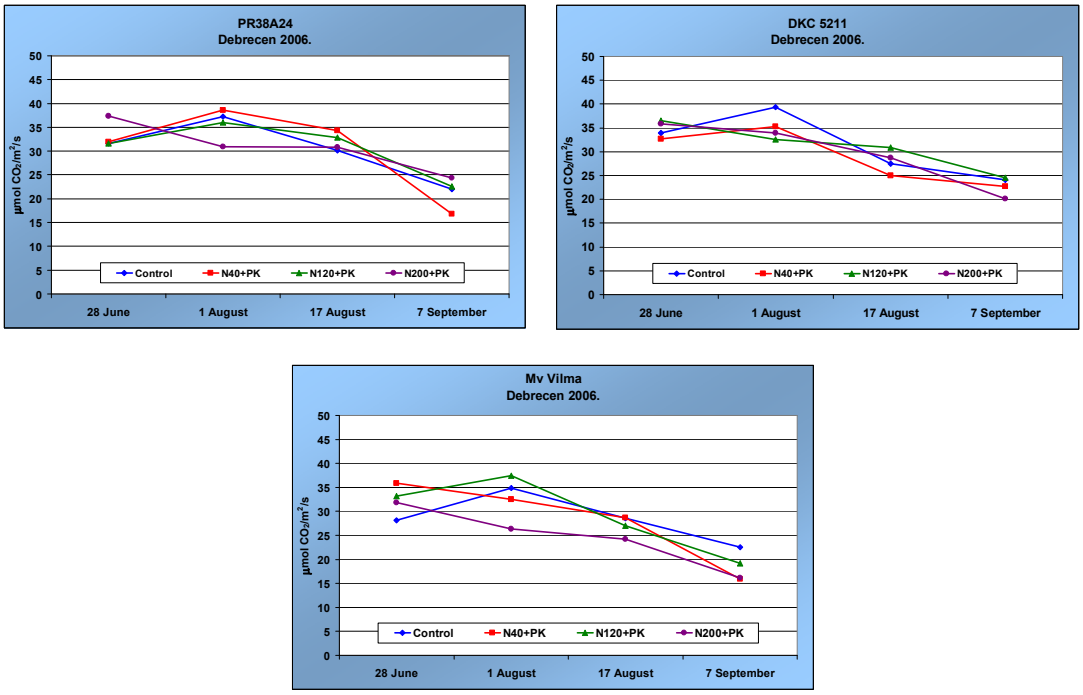
8. figure: **Effect of nutrient supply on the photosynthetic activity of maize hybrids (Debrecen, 2005)**



In 2006, photosynthesis reduced at different degrees in the different fertilizer levels with the advancement of the season. In the control and the N40+PK and N120+PK treatments, photosynthesis slightly increased at the beginning of August, then it reduced, while in the highest dosage treatment of N200+PK, the reduction was continuous from 28 June. In the average of hybrids, the differences were minimal

between the treatments, photosynthetic activity was the most intensive at the second measurement date for the N40+PK and N120+PK treatments with 37-37.3 µmol $CO_2/m^2/s$. Among the hybrids, only *PR39D81* had a higher than average photosynthetic activity of 42.4 and 45.0 µmol $CO_2/m^2/s$. The treatments N120 and N200+PK could increase photosynthesis only non-significantly as compared to the smallest fertilizer dosage (*Figure 9*).

9. figure: **Effect of nutrient supply on the photosynthetic activity of maize hybrids (Debrecen, 2006)**



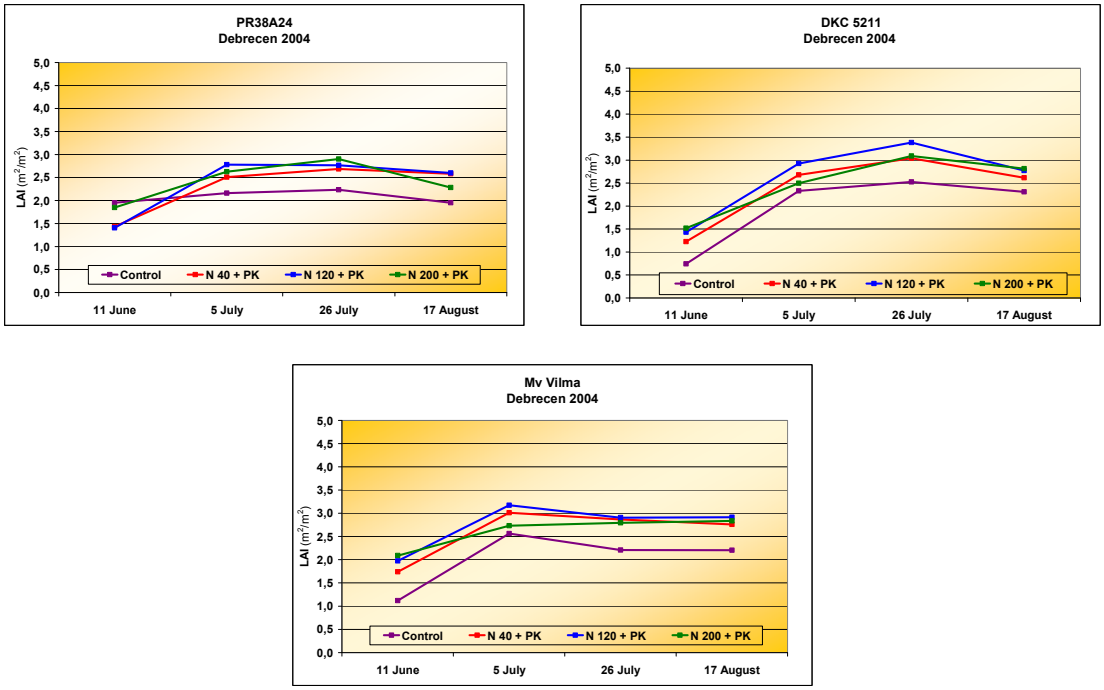
4.5. Relationship between fertilization and the leaf area of maize hybrids

In the study of the relationship between fertilization and leaf area, the hybrids *PR39D81*, *DK4626*, *PR38A24*, *DKC 5211* and *Mv Vilma* were involved. The measurements were performed in the control, the N40+PK, the N120+PK and N200+PK parcels at four dates.

Based on the results of 2004, it can be concluded that fertilization significantly increased the leaf area of maize in the average of hybrids as compared to the control, but the differences between the fertilization levels were not significant except for the first measurement when leaf area in the N200+PK treatment was significantly higher than that of the N40+PK treatment. The yields proved that the natural nutrient utilization ability of the hybrids DK4626, PR38A24, DKC 5211 and Mv Vilma was superior to that of the other studied hybrids and this favourable characteristic was

manifested also in leaf area. In these four hybrids, the smallest fertilizer dosage of N40+PK increased the leaf area index with 0.31-0.66 m2/m2 as compared to the control, so the leaf areas of the hybrids due to the better nutrient utilization ability were favourable also in the control parcel (0.74-2.65 m2/m2), while the leaf area of the hybrids PR39D81 increased even by 1.21 m2/m2 as a result of fertilization. Of course, the rainy year had a significant role in the favourable results obtained in the control treatment (*Figure 10*).

10. figure: **Effect of nutrient supply on the LAI of maize hybrids (Debrecen, 2004)**

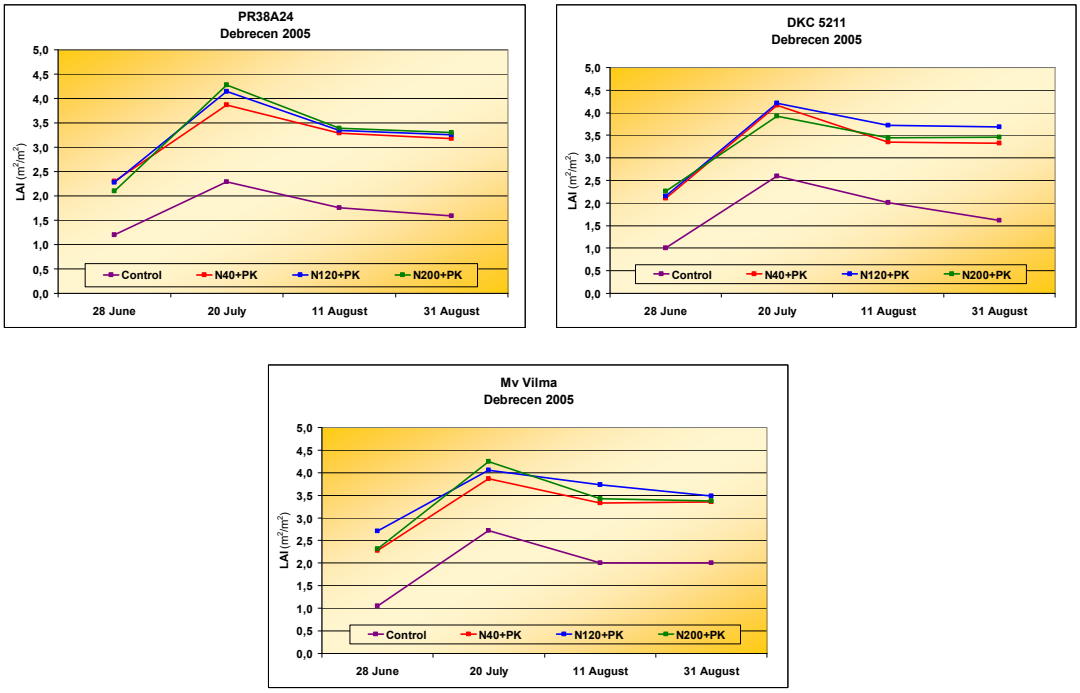


In 2005, the leaf area values were higher than those of the previous year which could be explained by the year effect. In this year, the more rainy months were in the vegetation period of maize, and the rainy weather in August resulted in a prolongation of the vegetation period and this could be the reason why the size of the leaf area did not change between 11 and 31 August. Furthermore, it can be concluded that the largest leaf area in the average of the hybrids was measured in the treatment N120+PK but this was not significantly higher than that of the treatments N40 and N200+PK. The leaf area measured in the control treatment was considerably lower than that of the fertilized parcels (*Figure 11*).

In 2006, the leaf area values were smaller than in the previous year, which was due to the lowest amount of precipitation in the vegetation period of maize among the

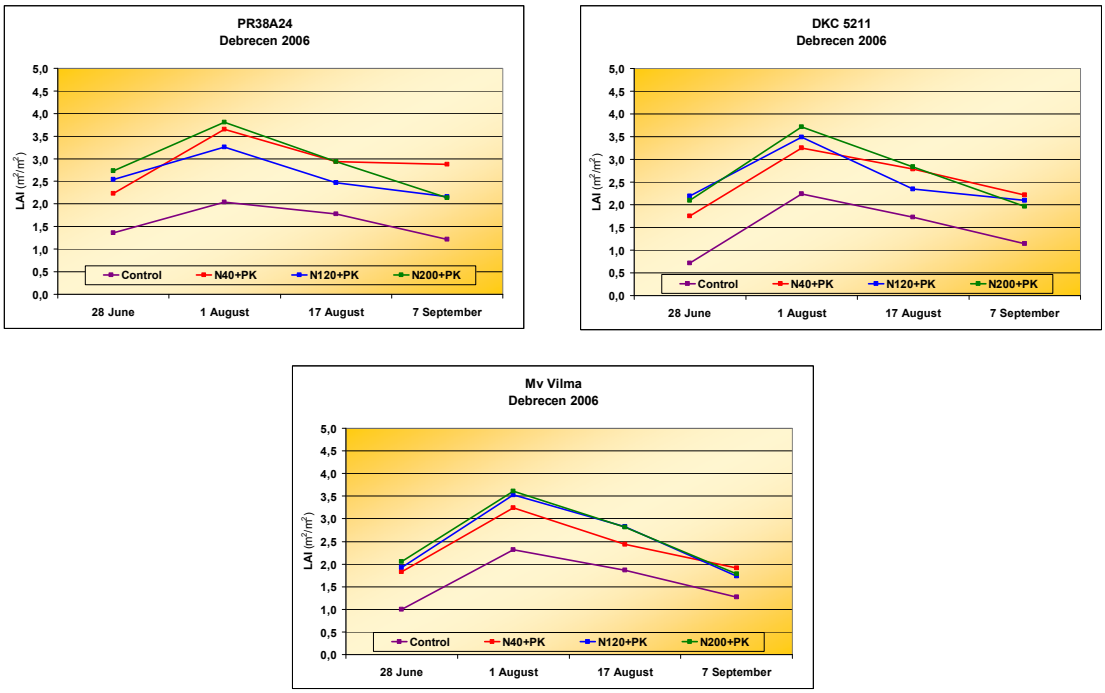
experimental years on the one hand, while on the other hand, the windstorm and hail in July damaged the leaves of the plants. Even the smallest dosage of fertilization resulted in a significant increment in leaf area as compared to the control.

11. figure: **Effect of nutrient supply on the LAI of maize hybrids (Debrecen, 2005)**



However, the N120+PK treatment increased the LAI in the average of the hybrids only non-significantly, but the leaves dried earlier at the N120 and N200+PK fertilizer levels. At the first two measurements, the difference between the treatments N40 and N200+PK was significant (0.38 and 0.40 m^2/m^2). The leaf area index was the highest for the hybrids *PR39D81*, *DK 4626* and *PR38A24,* their maximum leaf area values were almost the same, 3.81-3.91 m^2/m^2, while the values for the two other hybrids were somewhat lower, 3.62 and 3.72 m^2/m^2 (*Figure 12*). The leaf area index (LAI) of maize hybrids varied greatly depending on the year and the NPK treatment, which is related to the production of hybrids also.

12. figure: **Effect of nutrient supply on the LAI of maize hybrids (Debrecen, 2006)**



4.5.1. Study of the relationship between the leaf area index and yield of maize hybrids

In all three years of the experiment, the correlation coefficient between the yield and leaf area index of the hybrids *PR39D81, PR38A24, DKC 5211* and *Mv Vilma* ranged between 0.797 and 0.966. The correlation coefficient between the yield and leaf area of the hybrid *DK 4626* was 0.645 in 2004, that is the relationship was tight, while in 2005 and 2006, the relationship was very tight with values of 0.906 and 0.936 (*Table 6*). When studying the yields and the leaf areas, it can be concluded that the largest yields were obtained in the N120+PK treatment in the average of the hybrids in 2004 and 2005 with 12.58 and 13.51 t/ha and the leaf area per 1 m^2 was also the highest at this fertilization level, 2.6 and 3.39 m^2/m^2, respectively. In 2005, the higher leaf area index was probably due to the fact that the soil was saturated with water as a result of the previous rainy year, which assisted the formation of a larger green leaf area, so the plants could utilize sunlight at a larger area, which was also manifested in the dry matter accumulation.

In 2004-2005, the LAI value in the treatment without fertilization did not achieve 2 m^2/m^2 and the yield was also lower, 5.2 and 4.06 t/ha. In 2006, the average leaf area index of the hybrids was only 1.52 m^2/m^2 in the control treatment at a 3.33 t/ha yield, while at the fifth fertilization level the average yield of 9.67 t/ha was accompanied with

2.67 m^2/m^2 leaf area. Based on the study of the correlation, there was a very tight positive correlation between the yield and the leaf area index of the hybrids.

6. table: **Closeness of connection between yield of maize hybrids and LAI (Debrecen, 2004-2006)**

	2004	**2005**	**2006**
PR39D81	0.915**	0.818*	0.966**
DK 4626	0.645	0.906**	0.931**
PR38A24	0.829*	0.913**	0.880*
DKC 5211	0.891**	0.825*	0.860**
Mv Vilma	0.889**	0.949**	0.886**
A hibridek átlaga	0.797**	0.863**	0.848**

**Correlation is significant on 1% level
*Correlation is significant on 5% level

4.6. The effect of fertilization on the quality of maize hybrids

The quality of maize is determined primarily by genetic factors and their dominance is determined and modified by ecological and agrotechnical conditions and within these fertilization has a major role.

From the hybrids, we have studied the protein, starch and oil contents of the hybrids *PR37M34*, *DKC 5211* and *Mv Vilma* in the control, the N40+PK, N120+PK and N200+PK treatments in 2005 and 2006.

In 2005, the protein content of the studied hybrids ranged between 5.93 and 8.78%. The increase in the protein content due to the higher fertilizer dosages was different for the different hybrids. The protein content of the hybrid *PR37M34* ranged between 6.64 and 7.25% depending on the level of fertilization, it was the highest, 7.25%, in the treatment N120+PK. The protein content of the hybrid *DKC 5211* was 6.49% without fertilization, while in the N200+PK treatment, 7.82% was measured, there was a significant difference between the two. In 2005, the hybrid *Mv Vilma* achieved the highest protein content of 8.78% in the N200+PK treatment.

The starch content of the studied hybrids ranged between 64.48 and 68.00%. As a result of fertilization, the starch content of all the three hybrids reduced, there was no significant difference between the control and the treatment N40+PK in starch content, but a significant reduction was observed for the treatments N120+PK and N200+PK. The starch content of the hybrid *PR37M34* reduced continuously as a result of fertilization, it was 67.7% in the control treatment and 65.3% at the maximum fertilizer level. The starch content of the hybrid *DKC 5211* was 68% in the control parcel which

reduced to 66.69% in the treatment N120+PK, but the maximum fertilizer level decreased the starch content only slightly to 66.46%. The starch content of the hybrid *Mv Vilma* reduced at the greatest extent (3.12%) when comparing the control and the N200+PK treatments. Regarding the oil content, there were minimal differences between the hybrids and the fertilization levels, the difference between the smallest (3.29%) and largest (3.76%) values was 0.47%. The oil content of the hybrid *DKC 5211* was higher than that of the Pioneer and Martonvásár hybrids in all the four fertilization treatments. Its oil content ranged between 3.65 and 3.76%, but there were no significant differences between the treatments.

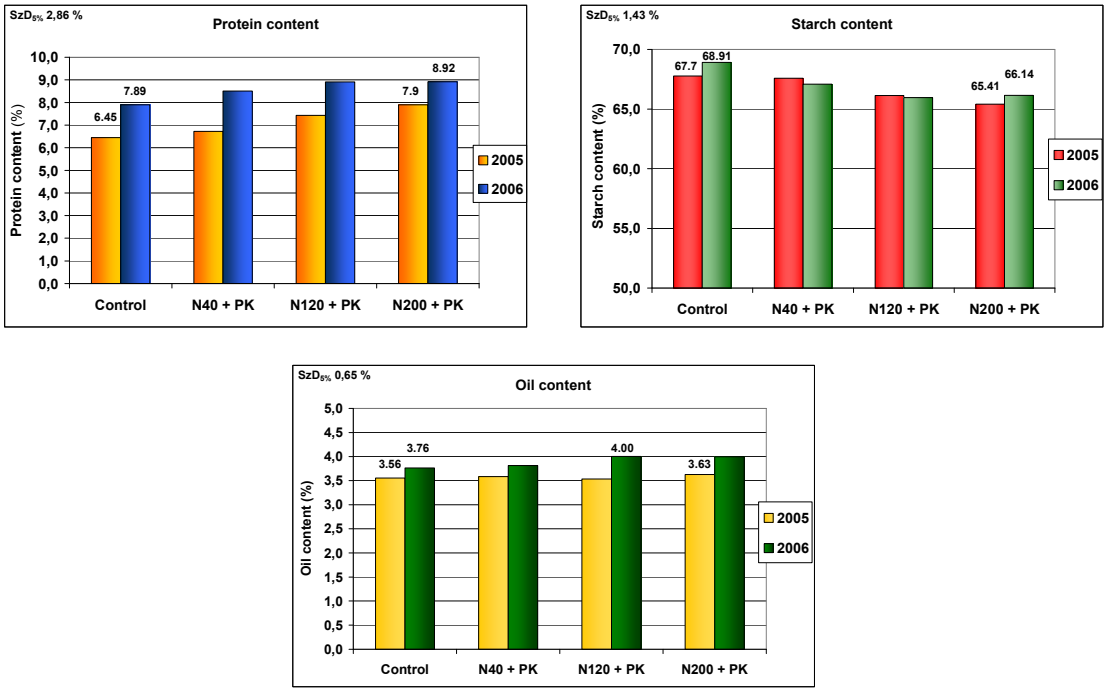
In 2006, the protein content of the hybrids varied between 7.89 and 9.75%. The protein content of the hybrid *PR34M37* was increased by fertilization, a significant difference as compared to the control (8.22%) was observed in the N40+PK treatment and the largest dosage fertilizer treatment with increments of 0.76 and 1.04%, respectively. Among the three studied hybrids, *DKC 5211* had the highest protein content of 9.75% at the fourth fertilization level. As compared to the yield of the control, its protein content was very high, 9.04% which was increased by the N120+PK treatment by 0.71%, however, a further increase in the fertilization did not result in an increase of the protein content. The protein content of the hybrid *Mv Vilma* was the lowest in the control parcel, 6.42%, the fertilizer dosage of N40+PK resulted in a significant increment of 1.26%, the next fertilizer dosage did not increase significantly the protein content. At higher fertilizer dosages, protein content exceeded 8%, but in the average of treatments it was 7.57%.

In 2006, the changes in the starch content as a result of fertilization were similar to those of the previous year, the yield of hybrids increased while the starch content was reduced. In the case of the hybrid *PR37M34,* there was a 2.9% difference in starch content between the untreated parcel (69.84%) and the treatment N200+PK (66.94%). The starch content of this hybrid was higher than the average of the hybrids at all fertilizer levels. The starch content of the hybrid *DKC 5211* was 66.58% without fertilization, which increased though not significantly as a result of the fertilization. Its starch content was lower than that of the other two hybrids, it was 66.1% in the average of the treatments. On the contrary, the starch content of *Mv Vilma* reduced significantly as a result of the fertilization, it was 70.31% in the control, while in the N40+PK treatment it was significantly lower by 3.66%. Further increase in the fertilization

reduced the starch content non-significantly, at the highest fertilizer dosage 64.9% was measured.

Supporting the results of 2005, the oil content of the hybrid *DKC 5211* was the highest in this year also, it exceeded 4% at all the four fertilization levels ranging between 4.03 and 4.17%, which was higher than the average of the hybrids. The oil content of the hybrids from Martonvásár was 3.75% in the control parcel and fertilization did not have a significant effect on it. The oil content of the hybrids was modified significantly only for the hybrid *PR37M34*, the fourth fertilization level increased it by 0.46 and 0.47% as compared to the control and the treatment N40+PK, respectively, which was higher than the $SD_{5\%}$ value (*Figure 13*).

13. figure: **The changing of protein, starch and oil content of maize hybrids at different fertilizer doses in 2005 and 2006 years**



Based on the results, it can be concluded that N fertilization increased the protein content of maize hybrids, while the increasing NPK fertilizer dosages reduced the starch content at different degrees for the different hybrids. The effect of fertilization on yield quantity and quality should be taken into consideration when determining the purpose of production (e.g. for animal feeding or bioethanol production), site- and hybrid-specific production technology should be applied which suits the purpose of production.

The results of the experiment in 2004-2006 is applied in the actual ecological circumstances and it can adapted in similar conditions.

5. NOVEL SCIENTIFIC RESULTS

1. With improving environmental conditions, the amount of yield and yield stability are enhanced which results in an increase in fertilization and the utilization of fertilizers. Based on the experimental results, the most stable was the yield of the control (without fertilization) treatment, but at a very low level of yield. Under improving conditions, the fertilizer dosage N_{120} P_{75} K_{90} kg/ha is satisfactory for realizing higher yields.
2. The natural nutrient utilization of maize hybrids and their fertilizer response vary greatly, which should be taken into consideration at fertilization and in the fertilization technology. In the studied years, the natural nutrient utilization ability of *PR36R10* and *Mv Vilma* and the yielding capacity of the early *PR37M34* and the late *Mv Vilma* proved to be excellent and the fertilizer response of *DK 4626*, *PR37M34*, *Sze SC 463 R* and *Mv Vilma* was outstanding.
3. The agroecological fertilizer optimum of analyzed maize hybrids is N_{120} P_{75}, K_{90} kg/ha active ingredient, which can be modified by the vegetation period of the hybrid, the year effect and other agrotechnical factors (plant density, crop protection etc.).
4. With increasing fertilization, the assimilation surface and lifespan of the plant increase at different levels for the different hybrids, so more radiation energy is absorbed by the plant which results in a yield increment. We found a very tight positive correlation between the leaf area index of the hybrids and their yields.
5. The water release dynamics of the hybrids in the maturity period varies with the hybrid, the year and the fertilization within the agrotechnical factors. There are hybrids which release water quickly in the first half of maturing such as *PR39D81, DK 440* or in the second half of the maturing such as *PR38A24*, *Sze SC 463R* and *Mv Vilma*. There is a tight relationship between the water release dynamics of the maturing time and the grain moisture content at harvest.
6. The water release dynamics of analyzed hybrids is favourable at the optimum N_{120}, P_{75}, K_{90} kg/ha fertilization. In the case of under- or overfertilization, the drying of bottom leaves is quick, which slows the release of grain moisture in a biological way (via the leaves). The physical release of grain moisture is a slow process which is very dependent upon the environmental factors.

7. The inner content parameters are greatly dependent upon the hybrid, the environmental factors, the year effect, the fertilization. Protein content of the hybrids *DKC 5211* and *Mv Vilma* and the starch content of the hybrids *PR37M3*4 were favourable. With increasing NPK fertilization, the amount of yield and protein content increased, while starch content might reduce, therefore, starch content can be augmented not by increasing the fertilizer dosage but by changing the nutrient ratio of N-P-K (reduction of N and increase of K). NPK fertilization does not cause a significant change in the oil content, it is determined primarily by genetic factors

6. RESULTS FOR PRACTICAL UTILIZATION

1. Knowledge of the fertilizer response of maize hybrids enables the selection of the hybrid best suited for the given ecological and agrotechnical conditions.
2. Yield safety of maize is enhanced by the optimal NPK fertilization adapted to the nutrient supply of the soil and the requirements of maize, while the improper fertilization reduces yield stability.
3. Based on the results, such fertilization technology can be applied which ensures the quality necessary for the production purpose, the maintenance of soil fertility in the long run and the requirements of environmental protection in addition to efficiency.
4. Knowledge of the water release dynamics of hybrids enables the selection of the proper hybrids with quicker water loss and via this the drying costs can be reduced.
5. The water release dynamics and the grain moisture content at harvest are influenced not only by the hybrid, but also by the fertilization from the agrotechnical factors and the year effect which should be taken into consideration in production.
6. The results make it possibly to increase the yield safety of maize by harmonizing the relationships between the ecological, biological and agrotechnical factors and by applying a hybrid-specific production technology.
7. If such agrotechnical conditions are provided which increase the leaf area, the photosynthetic activity and accordingly the higher dry matter assimilation, the yields can be increased and the application of a hybrid-specific production technology is promoted.

Main publication in connection with the dissertation

Publications with IF:

N. EL HALLOF–M. SÁRVÁRI (2005): Relationship between fertilization, leaf area index, photosynthetic activity and yield of hybrid. Cereal Research Communications. Vol. 33 No. 1. 181-184. p. 0,320

M. SÁRVÁRI–N. EL HALLOF (2005): The effect of artificial fertilizers on the photosynthetic activity of maize hybrids. Cereal Research Communications. Vol. 33 No. 1. 309-312. p. 0,320

N. El HALLOF-M. SÁRVÁRI (2006): Effect of different fertilizer doses on yield, LAI and photosynthetic activity of maize hybrids. Cereal Research Communications Vol. 34 No. 1. 441-444. p. 1,037

M. SÁRVÁRI-N. El HALLOF (2006): Effect of crop rotation and nutrient supply on the yield of maize. Cereal Research Communications Vol. 34 No. 1. 645-648. p. 1,037

M. SÁRVÁRI-N. EL HALLOF-ZS. MOLNÁR. (2007): Effect of determining factors on maize yield with special regards to plant density. Cereal Research Communications. Vol. 35. No. 2. Part 2. 1037-1040. p. 1,037

N. EL HALLOF-M. SÁRVÁRI (2007): Relationship between yield quality and quantity of maize hybrids and fertilizer. Cereal Research Communications. Vol. 35. No. 2. Part 1. 369-372. p. 1,037

Reviewed publications without IF:

EL HALLOF N.-SÁRVÁRI M. (2004): A vetésidő és a tápanyagellátás hatása a kukorica termésbiztonságára. Debreceni Egyetem, Agrártudományi Közlemények 13. Acta Agraria Debreceniensis, *(Szerk.: Jávor A.)* Különszám 2004. 75-80. p.

EL HALLOF N.-SÁRVÁRI M. (2005): A kukoricahibridek termőképessége és trágyareakciója. Agrártudományi Közlemények *(Szerk.: Jávor A.)* 2005/16 Különszám, 78-83. p.

EL HALLOF N.–SÁRVÁRI M. (2006): Az évjárat és a műtrágyázás hatása az eltérő genetikai adottságú kukoricahibridek termésére, a fotoszintézis és a levélterület alakulására. Agrártudományi Közlemények *(Szerk.: Jávor A.)* 2006/23. Különszám, 27-34. p.

Other publications:

N. EL HALLOF–M. SÁRVÁRI (2004): Effect of sowing time on the yield and the seed moisture content at harvest of maize. Proceedings of the III. Alps-Adria Scientific Workshop, Dubrovnik, *(Ed.: Sz. Hidvégi-Cs. Gyuricza)* 1-6 March 2004. 427-431. p.

EL HALLOF N.–SÁRVÁRI M. (2005): Az NPK műtrágyázás és a kukoricahibridek termése közötti összefüggés. Keszthely, XI. Ifjúsági Tudományos Fórum. 2005. március 24. CD kiadvány.

MOLNÁR ZS.–EL HALLOF N. (2006): A termesztéstechnológia kritikus elemeinek hatása a kukorica termésennyiségére és termésminőségére. V. Alföldi tudományos tájgazdálkodási napok, Mezőtúr, 2006. október 26-27. CD Kiadvány

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2006): A kukorica termesztéstechnológiájának meghatározó eleme. V. Alföldi tudományos tájgazdálkodási napok, Mezőtúr, 2006. október 26-27. CD Kiadvány

N. EL HALLOF–M. SÁRVÁRI (2004): Effect of sowing date on the productivity of maize. Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában, konferencia összefoglalók, Debrecen, 2004. 113. p.

N. EL HALLOF–M. SÁRVÁRI (2004): Connection among sowing time, yield and seed moisture content at harvest of maize. Natural Resources and sustainable development summaries, Oradea-Debrecen, 2004. 21. p.

SÁRVÁRI M.-EL HALLOF N. (2004): Magyarország kukoricatermesztésének 2004 évi tapasztalatai. Agro Naplo 2004/11-12. 15-17. p.

SÁRVÁRI M.-EL HALLOF N. (2005): A biológiai alapok hatása a kukorica termésbiztonságára. Agro Naplo 2005/2. 30-32. p.

SÁRVÁRI M.-EL HALLOF N. (2005): A vetésváltás jelentősége a kukoricatermesztésben. Agro Napló, IX. évfolyam, 2005/3. 12-14. p.

SÁRVÁRI M. - EL HALLOF N.–MOLNÁR ZS. (2005): Összefüggés a tőszám, a vetésidő és a kukorica termésbiztonsága között. Agro Napló, IX. évfolyam. 2005/4. 30-32. p.

SÁRVÁRI M. – EL HALLOF N.–MOLNÁR ZS. (2005): Kukorica vetőmagtermesztés technológiája Magyarországon. Értékálló aranykorona, V. évfolyam, 10. szám. 4-6. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS.–PÁLOVICS B. (2005): Magyarország 2005. évi kukoricatermesztési tapasztalatai, a jövő fejlesztési feladatai. Agro Napló, IX. évfolyam. 2005/11-12. 27-31. p.

EL HALLOF N. (2006): A kukorica termésbiztonságát befolyásoló tényezők elemzése. Értékálló aranykorona, VI. évfolyam I. szám. 4-6. p.

SÁRVÁRI M.–EL HALLOF N.–ZSOMBIK L. (2006): Végtermékcentrikus hibridválasztás általános és különleges szempontjai a kukoricatermesztésben. Agro Napló, X. évfolyam. 2006/02. 9-11. p.

EL HALLOF N. – MOLNÁR ZS. (2006): A kukorica tápanyagellátása gyengébb, vagy jobb adottságú területeken eltérő évjáratokban. Agrárágazat, Mezőgazdasági havilap, VII. évf. 3. szám. 56-60. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2006): A kukorica termesztése. Őstermelő, 2006/2. április–május, 60-62. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2006): Az amerikai kukoricabogár 2006. évi kártétele és az ellene való védekezés. Őstermelő, 2006/4. augusztus–szeptember, 32. p.

EL HALLOF N.–SÁRVÁRI M. (2006): Az NPK műtrágyázás és a kukoricahibridek termése közötti összefüggés. A racionális vetésforgók meghatározása a fenntartható növénytermesztésben. Szlovák-magyar projekt kiadvány. (Szerk.: Pepó Pé.-Vladimir P.) 2006. Október. CD-kiadvány. 134-144. p.

M. SÁRVÁRI–ZS. MOLNÁR–N. EL HALLOF (2006): Effect of sowing time and nutrient supply on the productivity of maize hybrids. The 4th international symposium, "Natural resources and sustainable development". Oradea, 10-11. October 2006. 355-362. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2006): Hibridspecifikus kukoricatermesztés. Magyar mezőgazdaság. 61. évfolyam, 2006. november 2. 12-14. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2006): A kukoricahibridek tápanyagigénye, trágyázása. Őstermelő. 2006/6. december-január, 24-27.p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2007): A tőszám hatása a kukoricahibridek termésére. Agrofórum Extra 17. 2007. január 7-9. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2007): A kukoricahibridek jelentősége a hibridspecifikus technológiákban. Értékálló aranykorona VII. évf. 1. sz. 2007. február. 7-9. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2007): Magyarország 2006. évi kukoricatermesztési eredményei. Agro Napló XI. évf. 2007/2. sz. 25-27. p.

SÁRVÁRI M.–EL HALLOF N.–MOLNÁR ZS. (2007): A kukorica alternatív hasznosítása. Őstermelő. 2007/1. február-március, 32-33. p.

SÁRVÁRI M.-EL HALLOF N.-MOLNÁR ZS. (2007): A napraforgó hozamát befolyásoló agrotechnikai tényezők. Értékálló aranykorona. VII. évf. 2. 17-19. p.

SÁRVÁRI M.-EL HALLOF N.-MOLNÁR ZS. (2007): Kukoricatermesztés helyzete, 2007. évi kilátások Magyarországon. Agrárunió VIII. évf. 5. sz. 32-33. p.

SÁRVÁRI M.-EL HALLOF N.-MOLNÁR ZS. (2007): Az őszi kalászosok vetőmag csávázása, fajtaválasztása. Értékálló Aranykorona. VII. évf. 6-7. sz. 4-6.p.

SÁRVÁRI M.-EL HALLOF N.-MOLNÁR ZS. (2007): A hibridválasztás szerepe a kukoricatermesztésben, a klimatikus tényezők alakulása, a kukoricahibridek értékmérő tulajdonságai. Agro Napló. 2007/12. 16-20. p.

SÁRVÁRI M.-EL HALLOF N.-MOLNÁR ZS. (2007-2008): A hibridválasztás szerepe a kukoricatermesztésben, a klimatikus tényezők alakulása, a kukoricahibridek értékmérő tulajdonságai. Agrárunió VIII. évf. 12-1. szám. 17-20. p.

SÁRVÁRI M.-EL HALLOF N.-MOLNÁR ZS. (2008): A klimatikus tényezők és változásának hatása a kukoricatermesztés biztonságára. Agrofórum. Extra 22. 8-12. p.

SÁRVÁRI M.-EL HALLOF N.-MOLNÁR ZS. (2008): Felértékelődő biológiai alapok. Magyar mezőgazdaság. 63. évf. 6. sz. 18-20. p.