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THESIS OF DOCTORAL DISSERTATION (Ph.D.)

THE EFFECT OF SOWING TIME AND NUTRIENT SUPPLY ON MAIZE YIELD

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I. TOPIC OF INTEREST

With the widespread use of maize hybrids and with the development of different hybrids, it became vital to analyse the average yield and quantity of different varieties. The different genetic potential of varieties and the question of optimals became also important. The generally sowed hybrids have different genetical background which provides them different performance under given agrotechnical and ecological features. The purpose of plant production is to reach the maximum possible genetic potential, besides ensuring maximum economic efficiency. The general price increase of the near past has also had an effect on the different kinds of power source, which results in the usage of modern variety-specific technologies in order to get good economic results.

Variety-specific technology means on one part, the professional and reasonable determination of sowing time. Good way of fertilization also belongs here, which has been analysed continously. One of the most important condition is to determine the sowing time and the rate of fertilization of a hybrid adapted to the character of the farm, landscape. This is an important question because different maize hybrids possess different genotype, which makes them adaptable different to the changes of agricultural techniques. Therefore, it is vital to know the specific reaction of hybrids, which provides us a security in production without any financial investment.

We need to pay more and more attention to the reaction of maize hybrids to fertilizers and to the biological bases, because maize hybrids can utilise nutrients in a different way. It means that hybrids are able to reach their potential at different level and at different rate of nutrients. Under different conditions of production, this can be utilised with varety-specific technology.

Sowing time is such a changeable element of agrotechnique which does not require extra cost, however, we can use it to increase the efficiency of production. One of the agritechniques, which can provide better efficiency, is the right sowing time. This can influence the moisture level of seed at harvest. Hybrids - with good cold tolerance at germination – sown early but stillwithin the optimal sowing time, have an earlier start of physiological ripening. This latter means the start of biological drying down. In this case maize can be harvested with low moisture level, even if drying down dynamics is of medium level.

The environmental changes (sunlight, soil temperature etc.), which are in connection with different sowing time, can modify the development of maize plant. The advantage of early sowing is that female flowering happens before July, that is the month of stress, because of water defficiency. As a consequence of late sowing, the seed moisture level increases at harvest time. Therefore, average yield can vary, which can be modified by the climatic features of the given year.

Domestic experience shows that inside of optimal sowing time of maize hybrids, earlier sowing results in bigger seed yield, better Harvest-index and lower seed moisture at harvest. This lower moisture level allows us to save high costs for the increasing price of energy sources in Hungary. Later sowing results in decreased thousand-seed mass, the number of seeds per cob, which greatly influence the possible maximum yield on a given area. Therefore, the total yield is affected by later sowing. This is the reason that besides other agritechniques, why it is vital to adapt optimal sowing time to the given hybrid. Those widely adaptable hybrids which are able to provide good yield under wide range of sowing time, that is they have good adaptability to different agritechnical conditions, are with higher importance.

In my thesis, I analyse the quantity of yield of maize hybrids under different sowing time and nutrient level. I also examine the effects of these factors on the timing of male- and female flowering, the seed moisture level, the rate of fertile and infertile maize plants on the given area, the reaction of maize to the nutrients, the formation of generative parts and changes of inner content.

II. MATERIAL AND METHOD

2.1. The antecedents of the research

In 2001-2003, in Hajdúböszörmény, we started a sowing time-fertilization trial, in which we analyzed the mutual effect of sowing time and fertilization on the maize yield, the yield forming elements and the formation of generative parts. We followed the effect of sowing time in an individual trial as well. Therefore, in Debrecen, in 2002 and in 2003 we also started a sowing time trial for maize, in which besides yiled analysis, we also measured the activity of photosynthesis. In Debrecen, we started another, the third individual trial between 2001 and 2003, where we analysed the independent effect of nutrient supply. In this trial we also measured photosynthesis. From the three trial, we can easily follow the effect of sowing time and nutrient supply.

In the trials, in 3 years (2001, 2002, 2003) we analysed the different maize hybrids for:

- yield capacity
- natural nutrient exploration- and utilisation capacity
- their reaction to sowing time
- the changes that happened in the phenological phases (springing, flowering etc.) of plants
- drying down capacity, dynamics of drying down, seed moisture level at harvest
- leaf area (LA) and leaf area index (LAI)
- the effect of variety, sowing time and fertilization on the total leaf area increase dynamics of maize hybrids
- the effect of NPK-fertilization and sowing time on the quality of hybrids with different genetical traits
- The effect of fertilization, sowing time and climatic traits on the photosynthetic activity of different hybrids.

We carried out the trials at the study farm of Debrecen University, Agricultural Centre, Department of Plant Production and in Hajdúböszörmény, in 2001, 2002, 2003.

2.2. The description of the weather of analysed years

2.2.1. The weather of 2001:

In 2001, during the growth of maize (IV-IX. months) there was 323 mm precipitation in total, while average value of 30 years is 345,1 mm.Compared to the average, there was 22,1 mm less precipitation. The distribution of precipitation during vegetation period was also unfavourable. Im May, there was only 1 mm rainfall, in August there was 30 mm which values are by 57,8 mm and by 30,7 mm less than the average of 30 years. Regarding average yield, the 89 mm precipitation of June was favourable.

In 2001, the yearly average temperature was 11,71 ºC, which is almost 2 ºC higher than the average of 30 years (9,84 ºC). During vegetation period, the average temperature was 17,48 ºC – 30 years average: 16,82 ºC. It was extraordinary warm in July and in August (21,8 ºC and 22 ºC average temperature).

2.2.2. The weather of 2002:

In 2002, between January and September there was average 10,7 mm more precipitation than the average of 30 years, however, its distribution was really unfavourable. During growing period (IV-IX. month) there was 27,9 mm more rainfall than the average of 30 years. It was especially unfavourable that in March (26, 0 mm), April (31,0 mm), May (33,0 mm), June (49 mm) the precipitation was significantly less than the average, therefore springing and initial growth of the plant was too long. There was more rainfall only in July (106,5 mm) and September (89,0 mm).

Regarding temperature, in 2002, the average temperature was higher in May (17,5 ºC) and June (19,0 ºC) than 30 years average. Hovewer, the yearly medium temperature does not reach the average (9,77 ºC)

2.2.3. The weather of 2003:

The year 2003 was really changeable regarding maize. Before vegetation period there was significant deficiency of precipitation, which hindered springing and early growth. It was followed by an average and a little drier May and June, which contnously hindered the dynamic growth of the plant, but helped the crop to overcome the critical spring time.

July was really rainy, followed by the big drought of August. In Debrecen, there was no rainfall in August, which totally stopped the favouable effect of the rain of the previous month. Furthermore, plants suffered because of water defficieny!

Based on these data, we can say that the year of 2001 was average or favourable to the growth of maize, while the weather of 2002 and 2003 was unfavourable.

1. table

The quantity of precipitation (mm), Debrecen 2001-2003.

	2001.	2002.	2003.	30 years average
January	45,0	16,5	12,0	***37,0***
February	15,5	41,0	17,0	***30,2***
March	90,5	26,0	13,5	***33,5***
April	49,0	31,0	19,0	***42,4***
May	1,0	33,0	64,4	***58,8***
June	89,0	49,0	40,8	***79,5***
July	36,5	106,5	130,8	***65,7***
August	30,0	64,5	0,0	***60,7***
September	117,5	89,0	45,6	***38,0***
October	0,0	52,5	100	***30,8***
November	21,0	41,5	29	***45,2***
December	6,0	26	20	***43,5***
Total	**501**	**576,5**	**492,1**	**565,3**

2.3. The characteristics of the soil:

In Hajdúböszörmény, the soil type of the trial was meadow soil. The area is seldom covered by water, but it is endangered in the years of inland waters. The level of soil water in case of average preicipitation is 2,0-2,5 m deep, but it can significantly come up in rainy years. The cultivated layer tends to get muddy with moisture, but it can also crack if gets dry. The organic material content is 4-5 % on the surface, going down it decreases suddenly – 40-60 cm deep it is only 1,5 %. Besides high humus content, the N availability is also good.

2 . table The characteristics of soil (Hajdúböszörmény):

pH		$CaCO_3$	y_1	hy_1	AL soluble		Humus	KA
H_2O	KCl	%			P_2O_5 mg/kg	K_2O mg/kg	%	
7,0	6,4	ny.	5,0	4,4	40	130	4,2	52

In Debrecen, the soil type of the trial area is alkalied chernozem, upper layer does not contain lime. The lower soil level is at 7-9 m deep. The layer of humus is 50-70 cm thick. The soil contains 2,57 % organic material. The *3. table* contains the results of the soil analysis. Because of lime deficiency, the upper layer of the soil is dry, it tends to crack in drought years.

3. table The characteristics of soil (Debrecen):

pH		$CaCO_3$ %	Y_1	Y_2	AL-soluble		Humus %	KA
H_2O	KCl				P_2O_5 mg/kg	K_2O mg/kg		
7,0	6,5	Ny	5,0	8,0	100,0	165,0	2,57	42,0

2.4. The data of agritechniques :

In the trials, besides three sowing time and the control, five level of nutrients formed the main treatment:

- the first sowing time; in the first ten days of April in each year (2001, 5 April,2002)
- the second sowing time took place in the second ten days of April in each year (20 April, 2001, 25. April 2002)
- the third sowing time took place either at the end of the first ten days of May, or at at the beginning of the second ten days (10 May 2001, 15 May 2002)

With the sowing times above, we tried to analyse the effect of an earlier and a later sowing time than the usual (about 20. April) in Hungary. In order to avoid the effect of different sowing times, we sowed the maize for the fertilizer trial between 10-20 April, each year.

4. table. The quantity of fertilizers in the treatments

	N	P_2O_5	K_2O	total kg/ha
control	-	-	-	**-**
1	40	25	30	**95**
2	80	50	60	**190**
3	120	75	90	**285**
4	160	100	120	**380**
5	200	125	150	**475**

Nutrient supply was the same in the combined sowing time-fertilization trial and in the fertilization trial, too. The quantity of fertilizer in the sowing time trial: N. 120 kg, P_2O_5: 80 kg and K_2O: 110 kg. Pre-crop: maize monoculture. Soil cultivation: deep plough at autumn at 30-35 cm deepness. At spring time plugh was followed by mounted rotary harrow, seed-bed was prepared by combinator. Plot size: 21 m^2 gross, 17,5 m^2 net. Site visit and recorded data: time of springing, time of appearance of male and female flowers, plant and cob tallness, number of fertile and infertile plants, the formation of generative parts. Plant protection: weed eradication (herbicides) meant plant protection in each year. In 2001, Tropazin was used for preemergent purpose, Titus Plus was used for postemergent purpose. In 2002, Primextra Gold for early postemergent treatment, Banvel 480 at 60 cm maize tallness, in 2003 Titus Plus was used. For the total eradication of all weeds, we slightly hand hoed the soil in each year in the trials. Harvest: the harvest of trial plants took place in the first half of October in each year. We harvested at the same time maize hybrids with different sowing time in order to compare them statistically.

2.5. Hybrids of the trial

5. table. Analysed hybrids 2001-2003

Years	Fertilization trial	Sowing time trial	Sowing time-fertilization trial
2001	PR39K38 FAO 280	The trial was launched in 2002.	Sprinter FAO 260
	DK 391 FAO 320		DK 355 FAO 280
	PR37M81 FAO 380		PR39K38 FAO 290
	Occitan FAO 380		DK 440 FAO 330
	DK 471 FAO 410		PR37M34 FAO 370
	Mv Maraton FAO 410		AW 043 FAO 380
	PR36R10 FAO 440		PR36R10 FAO 440
	Katinka FAO 480		Celest FAO 440
	Florencia FAO 530		DK 537 FAO 470
	DK 557 FAO 590		Florencia FAO 530
2002	PR39K38 FAO 280	PR39D81 FAO 280	Sprinter FAO 260
	DK 391 FAO 320	PR38K06 FAO 320	Goldacco FAO 290
	PR37M81 FAO 380	PR38A24 FAO 380	DK 391 FAO 320
	Occitan FAO 380	PR37M81 FAO 360	DK 440 FAO 330
	DK 471 FAO 410	PR37M34 FAO 360	PR37M81 FAO 360
	Mv Maraton FAO 410	PR36R10 FAO 480	PR37M34 FAO 360
	PR36R10 FAO 440	PR36N70 FAO 480	LG 23.93. FAO 380
	Katinka FAO 480	PR36B08 FAO 490	LG 23.72. FAO 390
	Florencia FAO 530	PR35P12 FAO 510	Celest FAO 440
	DK 557 FAO 590	PR34G13 FAO 530	DK 537 FAO 470
2003	PR39K38 FAO 280	PR38Y09	Goldacco FAO 290
	DK 391 FAO 320	PR38A67	Mv TC 277 FAO 320
	PR37M81 FAO 380	PR37D25	DK 440 FAO 330
	Occitan FAO 380	PR37M34	Sze SC 352 FAO 340
	DK 471 FAO 410	PR36M53	PR37M34 FAO 360
	Mv Maraton FAO 410	PR36N70	PR38A24 FAO 370
	PR36R10 FAO 440	PR34B97	LG33.62 FAO 370
	Katinka FAO 480	-	Hunor FAO 370
	Florencia FAO 530	-	DKC 5211 FAO 460
	DK 557 FAO 590	-	Celest FAO 470

III. RESULTS

3.1. The effect of nutrient supply on the formation of leaf area of maize hybrids and on the photosynthetic activity.

The yield of the maize can be influenced by plenty of factors (water-, nutrient deficiency, etc.). These factors all have effect on the leaf area size of the maize, which is the main location of photosynthesis. If we have the possibility to increase photosynthetic leaf area, that can have a positive effect on the yields. One possibility to increase photosynthetically active leaf area is to provide improving nutrient supply to the plant. Under optimal nutrient supply, the plant does not suffer from the stress caused by nutrient deficiency. This can ensure the development of the maximum genetically possible leaf area, which takes vital part in the production of organic material through photosynthesis.

In the vegetation period of the maize, in the three trial years (2001, 2002, 2003), we measured 5 and 4 times the leaf area index of the analysed hybrids. We made our measurments at the following fertilizer levels: control (no fertilization), and I-III. repeats at 1. (N: 40 kg/ha + P,K), at 3. (N: 120 kg/ha) and at 5. (N: 200 kg/ha+P,K).

In 2001, the control had only 1,65-2,09 m^2/m^2 leaf area index (LAI). Better nutrient supply resulted in strong leaf area increase of hybrids. The 1. fertilizer rate (40 kg N+P,K) had the greatest effect on the leaf area size. In this case hybrids reached 2,90-3,84 m^2/m^2 LAI value. Further increase of fertilization rate did not result in such a big increase of leaf area size of hybrids. However, maximum value was reached at 3,08-3,92 m^2/m^2 LAI.

We also analysed significant difference among hybrids, too. In 2001, in our trials there we no hybrids of very early- and early maturity, however we found significant difference between hybrids of middle-late and late maturity. Tle Leaf Area Index (LAI) of hybrids of middle maturity (PR36R10, Katinka) was by 0,3-0,4 m^2/m^2 LAI less than of hybrids of late maturity. The difference was significant at 0,1 % level, the calculated $LSD_{5\%}$ value is: 0,11

In 2002, hybrids reached their leaf area maximum already by the middle of June. This is 3-4 weeks earlier than in 2001. This fast development persisted till the end of the vegetation period, which can be explained by high temperature and defficiency of rainfall. After this time, no increase happened to leaf area. As for the control, in 2002 hybrdis had better leaf area size, reached 1,74-2,53 m^2/m^2 LAI value. In 2002, with the increase of nutrient supply, the leaf area of hybrids became bigger. The 1. fertilizer level (40 kg N+P,K) had the greatest effect on leaf area size. At this rate of fertilizer, hybrids reached 2,98-3,93 m^2/m^2 LAI value. With the further increase of fertilizer rate, the increase of leaf area of hybrids slowed down, but maximum value – 3,68-4,24 m^2/m^2 LAI - was reached in 2002 at higher fertilizer rate, too (3. fertilizer level 120 kg N+PK).

In 2002, in our trial, we already had maize hybrids of really early- and early matrurity, besides ones of middle and late maturity. The leaf area of hybrids of really early and early maturity (PR39K08, PR37M81) was by 0,4-0,5 m^2/m^2 LAI value less, then of late maturity ones. The difference among hybrids was significant at 0,1%, the calculated $LSD_{5\%}$ value: 0,24 *(6. table)*.

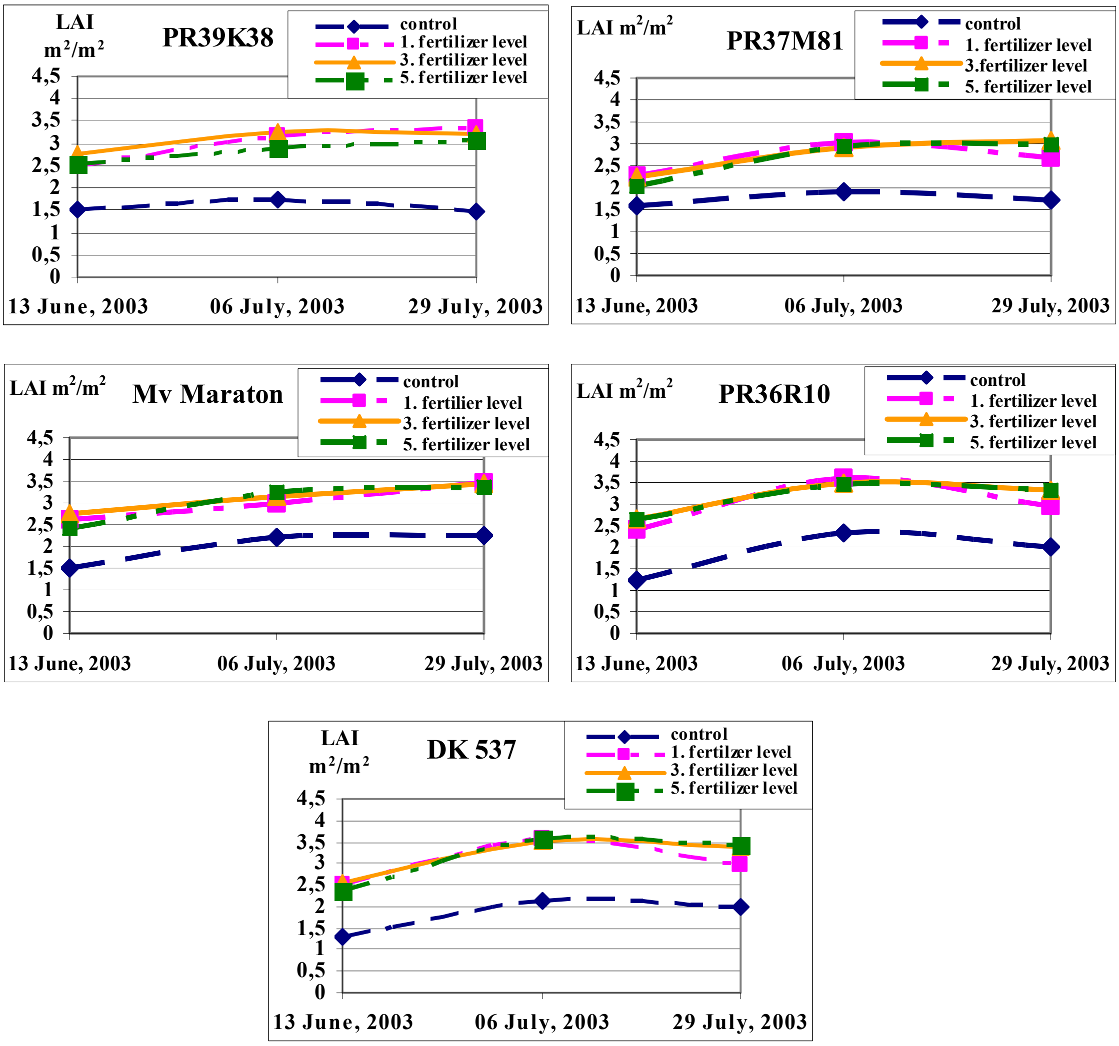
6. table. The LAI value of hybrids in 2002

Hybrid	**2002**	
	LAI m^2/m^2	**$SzD_{5\%}$**
PR39K38	3,176	**0,24**
PR37M81	2,919	
Mv Maraton	3,635	
PR36R10	3,504	
DK 557	3,598	

In 2003, the maize hybrids reached their maximum leaf area size in July. It is 2-3 weeks earlier than in 2001, similarly to the values measured in 2002. This can be explained by the strong drought at summer. Drought was so heavy that at the time of the fourth planned leaf measure (25 August), we could already not find green leaf, plants were totally dry. In 2003, the control plants had more favourable leaf area. Their LAI value was 1,73-2,33 m^2/m^2

Better nutrient supply resulted in significantly bigger leaf area. The 1. fertilizer dosage (40 kg N+P,K) had the greatest effect on leaf area in this year, too. At this dosage of fertilizer, hybrids could reach 2,99 – 3,61 m^2/m^2 LAI value *(1. figure).* With the further increase of fertilizer level, the leaf area of hybrids did not increase significantly. From the five analysed hybrids, three reached the maximum at this level of fertilizer. This can probably explained by the depressive effect of high fertilizer levels under dry conditions. In 2003, we also analysed maize hybrids of really-early and early maturity, besides having hybrids of middle- and late maturity, too. The leaf area of hybrids of really early- and early maturity (PR39K38, PR37M81) was by 0,4-0,6 m^2/m^2 LAI value less, then of late maturing hybrids. The difference between the hybrids was significant at 5,0 %, the calculated value of $LSD_{5\%}$: 0,37.

1. figure The leaf area index (LAI) of the analysed hybrids in 2003



We can say that there was significant difference among leaf areas measured on different fertilizing levels in 2001 and 2002 as well. We evaluated the measured leaf areas with variant-analysis. We can also determine that fertilization each time resulted in significant leaf are increase of the analysed hybrids *(7. table)*.

7. table: the LAI values of treatments in 2001-2003

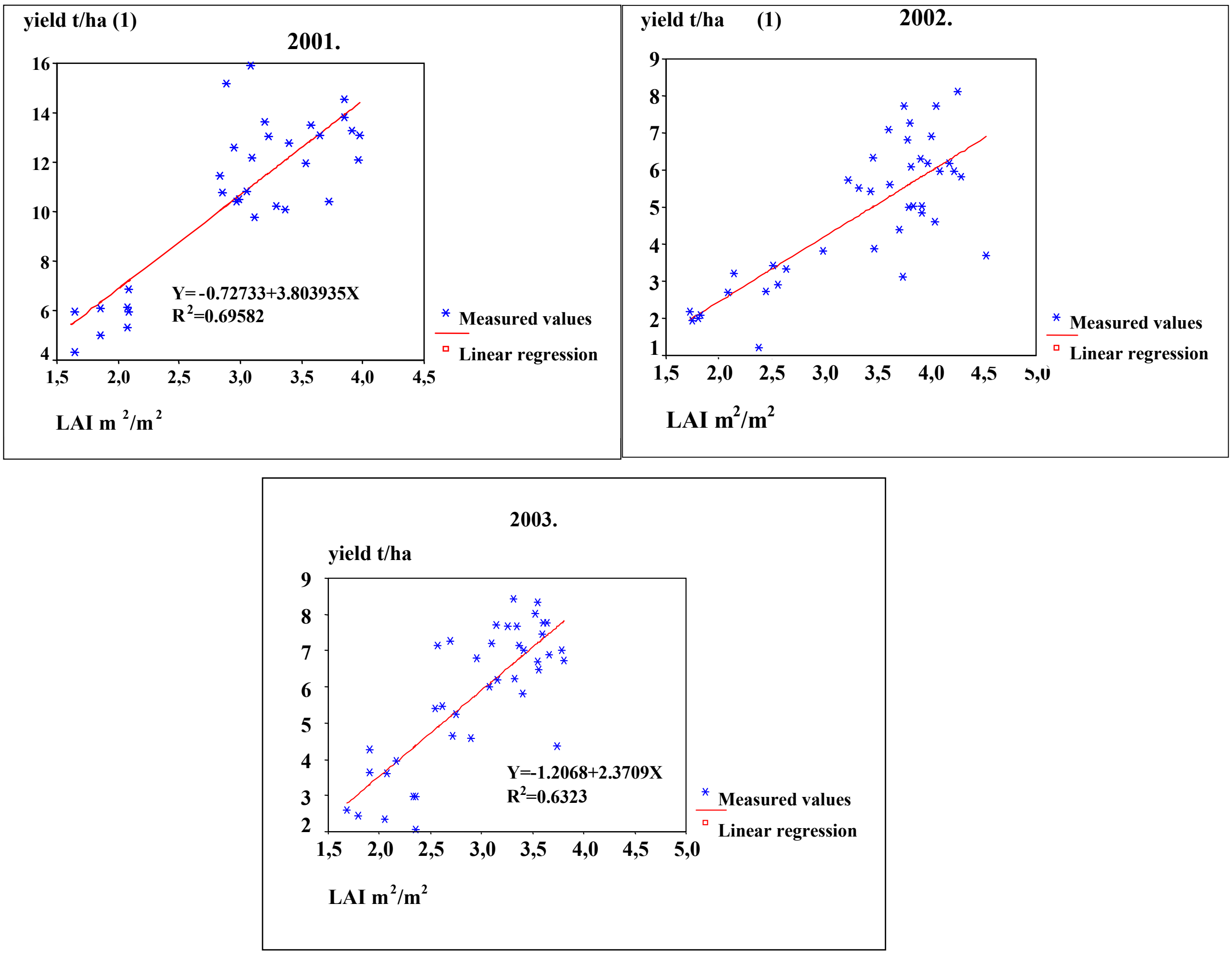
Treatment	2001		2002		2003	
	LAI m^2/m^2	$LSD_{5\%}$	LAI m^2/m^2	$LSD_{5\%}$	LAI m^2/m^2	$LSD_{5\%}$
Control	1,920	**0,10**	2,123	**0,21**	2,059	**0,33**
40 kg N+P,K	3,293		3,566		3,267	
120 kg N+P,K	3,319		3,977		3,271	
200 kg N+P,K	3,432		3,799		3,225	

The correlation is really strong, because the calculated R^2 values are really big: In 2001: 0,960-0,992 in 2002: 0,897-0,962, and in 2003 between 0,887-0,978 .

3.2. The results of maize seed yield depending on leaf area

The analysis of linear regression shows that the effect of leaf area index (LAI) on the quantity of yields is really strong. Despite the different leaf area indexes in 2001, 2002 and 2003, furthermore, in spite of yields of 2001-2003 vary in a big scale, there were no really differences in the individual years, the correlation is really strong (R^2 value: varied between 0,69582 and 0,61330).

2. figure. The linear regression between LAI and the yield in 2001-2003.



The formed leaf area (LA) and leaf area index of a given area unit (LAI) have a significant effect on yields. The bigger leaf area can better utilise the global rays and its organic material production also improves. However, as soon as the plants reaches a certain leaf area, the yields will not get bigger. The reason is that the foliage has a self-shadow effect and because of the increased transpiration of the plant, there is no organic material accumulation.

3.3. The photosynthetic activity of maize hybrids

In order to analyse photosynthetic activity, we measured photosynthesis on the arable land several times, which could well describe the photosynthetic activity of plants on the plot.

8. table The photosynthetic activity of maize hybrids in 2001

(fixed CO_2 mmol/m^2/sec)

25 June 2001					
	Katinka	**PR36R10**	**Florencia**	**DK 557**	**average**
control	40,13	38,03	41,08	35,18	**38,60**
1. tr.	33,58	37,88	40,96	40,77	**38,30**
3. tr.	38,53	41,10	39,91	40,50	**40,01**
5. tr.	48,87	37,86	36,37	44,15	**41,81**
17 July 2001					
	Katinka	**PR36R10**	**Florencia**	**DK 557**	**average**
control	24,69	25,51	17,79	18,93	**21,73**
1. tr.	20,12	16,77	14,99	16,51	**17,10**
3. tr.	27,04	22,44	16,28	15,32	**20,27**
5. tr.	18,85	15,43	8,73	13,68	**14,17**
13 August 2001					
	Katinka	**PR36R10**	**Florencia**	**DK 557**	**average**
control	14,78	15,59	13,88	13,71	**14,49**
1. tr.	23,51	21,78	22,26	19,95	**21,88**
3. tr.	26,99	21,41	25,65	16,91	**22,74**
5. tr.	22,11	17,94	22,28	21,72	**21,01**
29 August 2001					
	Katinka	**PR36R10**	**Florencia**	**DK 557**	**average**
Control	9,65	10,59	7,64	4,47	**8,09**
1. tr.	21,95	15,73	17,89	20,51	**19,02**
3. tr.	15,95	16,82	21,75	20,09	**18,65**
5. tr.	16,39	20,41	14,22	18,31	**17,33**

The older the maize hybrids are, the photosynthetic activity decrease the more. This is a gradual fall, the last measure time shows that old plants posses only 40-45 % photosynthetic activity of the younger plants. Nutrient supply also has an important effect, because as older plant tissues get older, the control plot fixed far the less CO_2 quantity. Plots with good nutrient supply, especially plants with the 3. and the 1. fertilizer level showed greater photosynthetic activity, while the 5. fertilizer level resulted in less CO_2 fixation. The most obvious result of the last measuring time is that the photosynthesis of plots with better nutrient supply did not decrease as much as of plants, which suffer from nutrient defficiency on the control plots. We found out that nutrient supply increased not only the leaf area in 2001, but photosynthesis took place for a longer time and in a greater pace than on control plots with poor nutrient supply. In 2002 and in 2003 the results we received are similar to those of year 2001.

3.4. The effect of nutrient supply on the drying down dynamics of maize hybrids and on the seed moisture level at harvest

Between 2001 and 2003 we measured the drying down of 4 and 5 maize hybrids till harvest, every 7. day. The treatments clearly showed that control hybrids had higher seed moisture level than of those hybrids which received fertilizers. This resulted in 4-5 % difference at harvest. Regarding all the hybrids, the 3. fertilizer level showed the most favourable seed moisture level *(9. table).*

9. table. Analyses of drying down, results 2001.

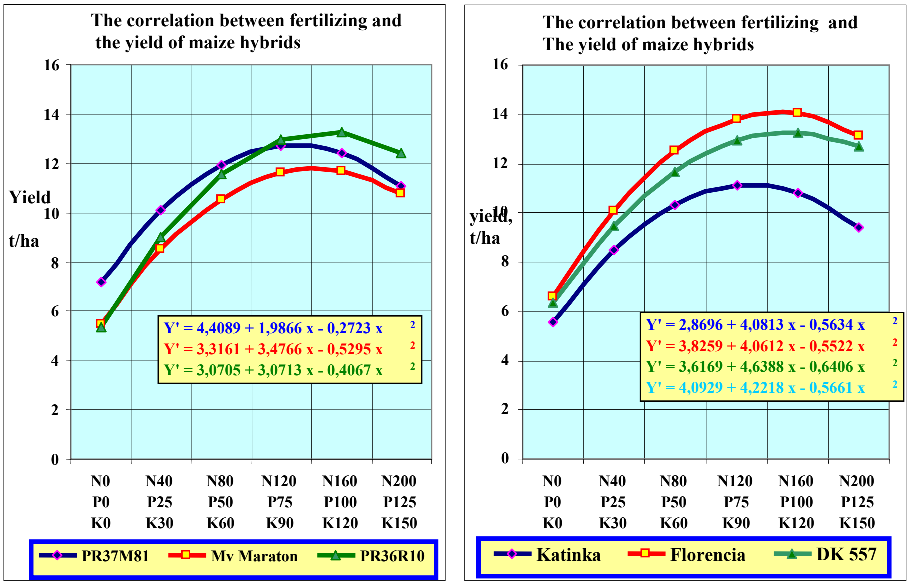
date	Spread fertilizer	Moisture level %	$LSD_{5\%}$
27 August 2001	Control	**44,500**	**1,45** ***
	1. fertilizer level	**39,000**	
	3. fertilizer level	**37,500**	
	5. fertilizer level	**39,000**	
03 September 2001	Control	**39,500**	**n.sz.**
	1. fertilizer level	**38,750**	
	3. fertilizer level	**39,000**	
	5. fertilizer level	**39,000**	
10 September 2001	Control	**37,250**	**1,45** ***
	1. fertilizer level	**35,250**	
	3. fertilizer level	**34,250**	
	5. fertilizer level	**34,750**	
17 September 2001	Control	**35,750**	**1,35** ***
	1. fertilizer level	**32,000**	
	3. fertilizer level	**31,250**	
	5. fertilizer level	**31,750**	
24 September 2001	Control	**32,000**	**1,30** ***
	1. fertilizer level	**29,750**	
	3. fertilizer level	**29,000**	
	5. fertilizer level	**30,000**	
05 October 2001	Control	**26,750**	**1,20** ***
	1. fertilizer level	**25,000**	
	3. fertilizer level	**24,250**	
	5. fertilizer level	**25,125**	

In 2002 and 2003, the measurements of drying down dynamics provided similar results to those of 2001.

3.5. The evaluation of maize hybrids on their yield capacity, nutrient exploration and reaction to fertilizers

Nutrient supply has a significant effect on the increased yield of maize hybrids. It is quite obvious that smaller starting dosage of fertilizer has the biggest yield increasing effect. Later on, the gradually increasing dosage of fertilizers results in a smaller increase of yield. As soon as fertilizing reaches a certain point, it will not increase yields anymore. In case of drought, big dosage of fertilizer can result in decreased yields. During the trials it was our target to determine the fertilizer dosage of maize hybrids which is optimal both in agricultural and economic sense.

3. figure



In 2001, PR36R10, DK 557 and Florencia showed the best reaction to ferilizers, while Katinka and Mv Maraton hybrids had the worst results. As we were evaluating the correlations, we realized that there is a statistically provable difference between the effect of fertilization and the different yield potential of hybrids. The effect of fertilization is really significant, especially in the case of the first two fertilizing level. *(10. table)*. We show in this table the received yields in the average of the total hybrids in oder to be able to describe the effect of fertilization.

10. table The correlation of fertilization and yield in the average of the evaluated hybrids, 2001.

	Average yield t/ha	$LSD_{5\%}$
Control	5,355	**0,82**
1. fertilizer level	10,487	
2. fertilizer level	11,609	
3. fertilizer level	11,999	
4. fertilizer level	11,887	
5. fertilizer level	12,132	

The data of the table clearly shows that in 2001 only the first two fertilizer levels had significant higher yield resulting effect, however, the effect of higher level of fertilizer is not provable.

It is also well-known that resulting from the different genetic background of hybrids, their reaction to fertilizers is also different. Therefore, we evaluated the yield capacity and reaction on fertilizing of hybrids respectively. This can ensure that the hybrids with the best characters are easy to determine.

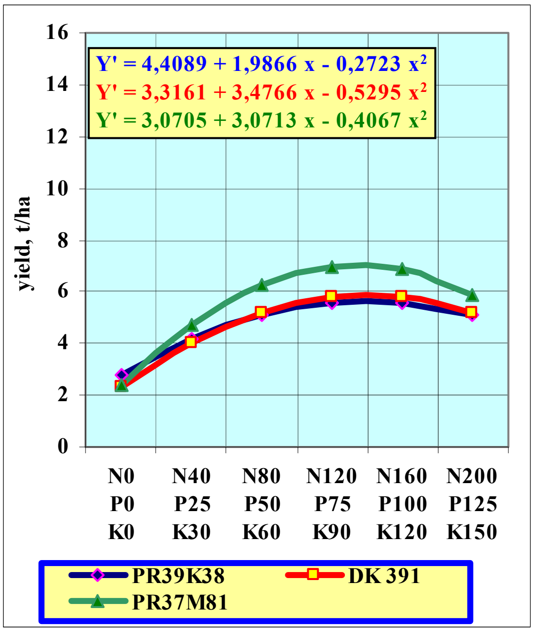
The PR36R10, the Florencia and the DK 557 hybrids possess the best reaction to fertilizers among evaluated hybrids. These hybrids reach their maximum yield at the 3. and the 4. fertilizer leves, though significant difference can be proved only in case of the first fertilizing level. This also shows their excellent nutrient-utilising ability. It is advisable to use higher level of fertilizer (120 kg/ha N+P,K) for these hybrids, because the yield increase for one unit of fertilizer is also favourable (12,0-19,72 kg yield/1 kg fertilizer active ingredient) at higher, 3. and 4. fertilizer level.

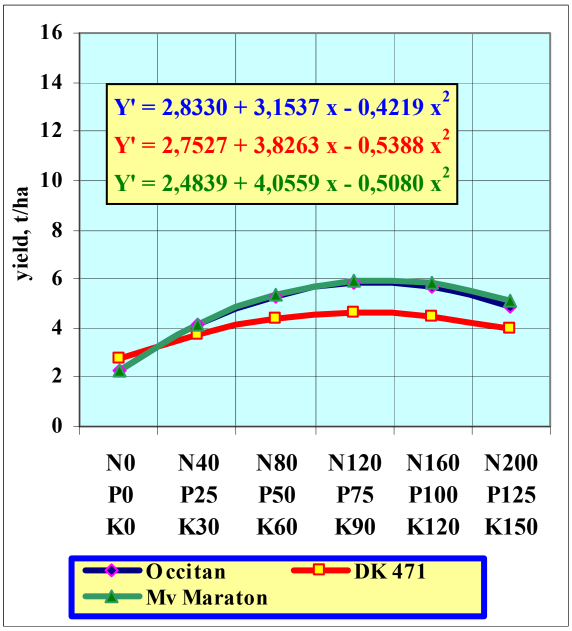
In 2002, owing to the bad weather, the yield of the evaluated hybrids are significantly less than in 2001. From the results it is easy to see that drought year made nutrient-reaction curves flatter, and smaller than in the previous year. The reason for this is that maize is able to absorb nutrients of water-solved form from the soil. In case of drought, there is no enough available water for the maize to absorb nutrients, therefore nutrient utilization gets worse.

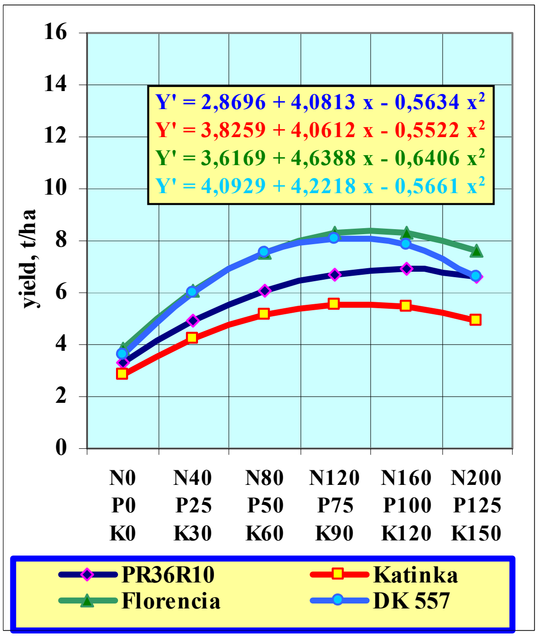
Even in a year of drought, Florencia, DK 557 and PR37M81 hybrids had the best reaction to fertilizers. Despite of the defficiency of precipitation, it is possible to observe differences among maize hybrids of different maturity. Hybrids of really-early maturity type had less yield (3-6 tonnes/ha) than of hybrids belonging to the late maturing group (4-8 tonnes/ha).

The evaluation of effect of fertilizing showed very well the close correlation between the water availability of the year and the utilization of fertilizers in 2002. This year the small amount of precipitation did not allow the fertilizer to result in significant yield increase, because there was not enough water in the soil to absorb nutrients. As a consequence, only the first fertilizer level increased the yields significantly, further fertilization did not cause significant yield increase. Furthermore, after the 3. fertilizing level, we could observe a decrease in yields. As an opposite, in 2001, the 2. fertilizer level also caused significant yield increase compared to the 1. fertilizing level. Its reason is more harmonic water supply.

4. figure The correlation between fertilization and the yield of maize hybrids, 2002







11. table. The correlation between fertilization and yield; in the average of the hybrids

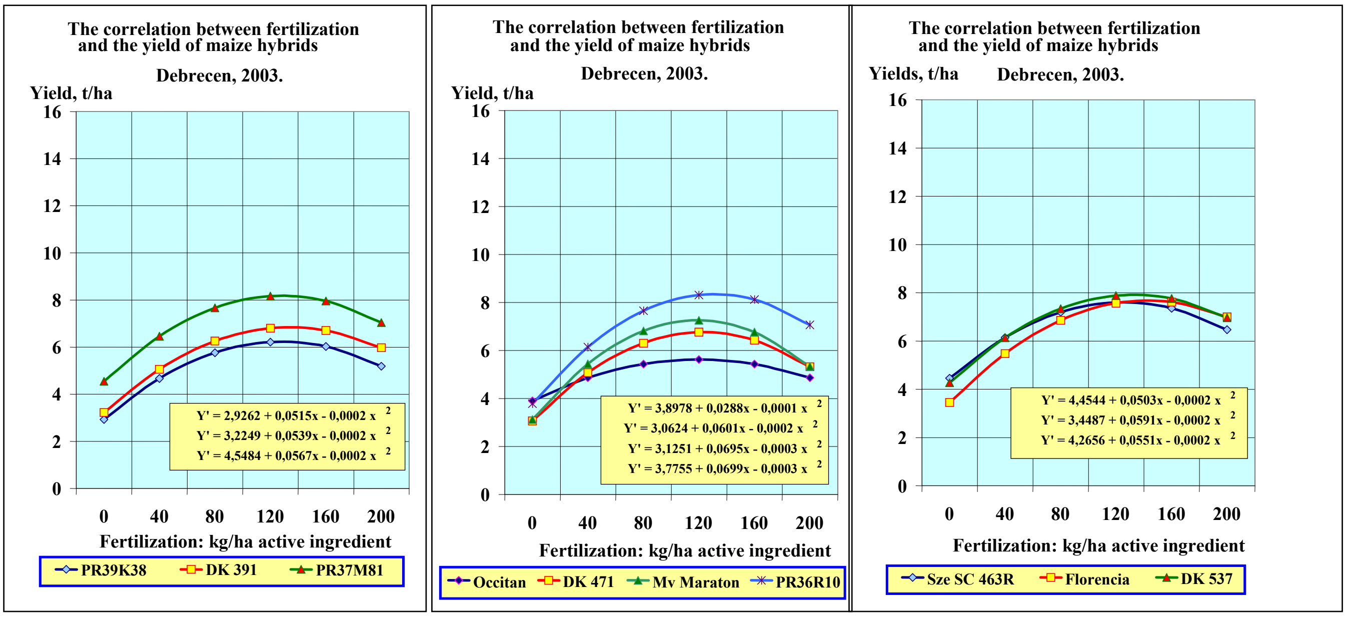
	Average yield t/ha	$LSD_{5\%}$
Control	2,346	0,59
1. fertilizer level	5,482	
2. fertilizer level	5,786	
3. fertilizer level	6,170	
4. fertilizer level	5,652	
5. fertilizer level	6,016	

In 2003, as we evaluate the yields, we can observe that the maize hybrids of early maturity can maximum reach 6-7 tonnes/ha yield, while hybrids of late maturity can reach maximum

7-8 tonnes/ha. This latter yield is also below 2001 yields. This can be explained – similarly to the year of 2002 - with the unfavourable weather conditions, and the persistent precipitation defficiency. From the ten evaluated hybrids, extraordinary good yields we achieved with PR37M81, PR36R10 and the DK 537 hybrids. The yield of these hybrids were close to the the 8 tonnes/ha. PR37M81 hybrid reached even more.

In 2003, PR37M81, DK 537 and Florencia hybrids had the best reaction to fertilizers, but the reaction of Sze SC 463R, which we evaluated for the first time in 2003, was also good *(5. figure)*.

5. figure The correlation between fertilization and the yield of maize hybrids, 2003



The evaluation of the effect of fertilization clearly shows the effect of a dry year on the nutrient absorption and on the dynamics of crop formation. This year the little rainfall did not allow the fertilizer to bring about significant increase in yields, because in case of water defficiency, maize was not able absorb the necessary nutrient quantity which provides higher yields. Therefore, average yields were increased significantly by the first fertilizer level (40 kg/ha N+P,K). Any further dosage of fertilizer did not cause significant increase in yields. Fertilizer dosage more than the 2. fertilizer level caused yield decrease in maize hybrids in 2003 *(12. table)*.

12. table. The correlation between fertilization and yield in the average of hybrids, 2003.

	Average yield t/ha	$LSD_{5\%}$
Control	3,006***	**0,35**
1. fertilizer level	6,656	
2. fertilizer level	6,881	
3. fertilizer level	6,813	
4. fertilizer level	6,342	
5. fertilizer level	6,643	

3.6. The change of yield forming elements at different nutrient levels

The effect of nutrient supply on the thousand seed mass of the maize is very significant. We observed the increase of the thousand seed mass in case of fertilized treatments compared to the control ones. This difference was significant.

13. table. The effect of NPK fertilization on the change of the thousand seed mass in the average of the evaluated hybrids, 200-2003 .

	2001.		2002.		2003.	
	Thousand seed mass (g)	$LSD_{5\%}$	Thousand seed mass (g)	$LSD_{5\%}$	Thousand seed mass (g)	$LSD_{5\%}$
Control	248,958	**11,02**	258,833	**9,78**	244,833	**9,35**
1. fertilizer level	288,750		309,333		298,500	
2. fertilizer level	292,500		312,333		316,667	
3. fertilizer level	302,292		323,500		319,833	
4. fertilizer level	297,708		315,500		319,667	
5. fertilizer level	302,083		319,667		319,833	

At the evaluation of yield forming elements, we paid attention to the number of rows on the cob. As a result of our analysis, we can say that both in 2001 and in 2002 there was significant increase in the number of rows on the cob as a result of fertilization levels. However, in 2003, fertilization did not significantly increase the number of rows *(14. table)*.

14. table Correlation between NPK fertilization and the counted number of cob rows of maize hybrids 2001-2003.

	2001.		2002.		2003.	
	Number of rows	$LSD_{5\%}$	Number of rows	$LSD_{5\%}$	Number of row	$LSD_{5\%}$
Control	13,767	**0,49**	13,267	**0,51**	14,140	**0,46**
1. fertilizer level	14,875		15,287		14,373	
2. fertilizer level	14,875		15,473		14,380	
3. fertilizer level	14,967		15,433		13,940	
4. fertilizer level	14,858		15,513		14,067	
5. fertilizer level	14,908		15,373		14,293	

The formation of seed number of one row was the last analysed parameter of yield forming elements. We could determine that there is a significant change in the number of seeds with the change of nutrient supply. In both year, with the increase of fertilizer level, we experienced the significant increase of seed number *(15. table)*.

15. table The effect of NPK fertilization on the seed number 2001-2003.

	2001.		**2002.**		**2003.**	
	Number of seeds in 1 row	**LSD$_{5\%}$**	**Number of seeds in 1 row**	**LSD$_{5\%}$**	**Number of seeds in 1 row**	**LSD$_{5\%}$**
Control	21,967	**1,82**	20,760	**1,81**	23,080	**1,29**
1. fertilizer level	29,913		29,913		32,127	
2. fertilizer level	31,308		29,980		31,533	
3. fertilizer level	30,850		30,000		31,773	
4. fertilizer level	31,200		28,673		30,947	
5. fertilizer level	30,458		29,520		30,520	

3.7. The effect of sowing time on the intensity of photosynthesis

Between 2001 and 2003, we measured the intensity of photosynthesis. Based on data received, we could make the same statement each year. The latest sowing time, that is the IV. sowing provided the most intesnse CO_2 fixation, which shows the intense operation of the photosynthetic apparatus of the plant. In the evaluated years, precipitation defficiency significantly affected the photosynthesis of plants. Stress caused by drought did bring about the faster aging of the tissues, therefore in many cases, we found significant difference between the photosynthesis of the younger and the older crops *(16. table)*.

As we are heading to the end of the vegetation period, earlier sown maize reach maturity earlier, where we experience gradually decreased CO_2 fixation. Later sowed maize (III-IV. sowing time) even in this phase is able to fix more CO_2, because the maturity of these crops occur later. This is the reason why the maturity of later sowed maize can get really late, so their drying down can slow really down in case of cold late autumn.

16. table The quantity of fixed CO_2 at different sowing times (mmol/m^2/sec)

17 June 2003				
	PR38Y09	**PR37M34**	**PR36N70**	**average**
I. sowing time	30,78	34,46	28,88	**31,37**
II. sowing time	28,27	30,68	34,42	**31,12**
III. sowing time	30,88	33,37	29,06	**31,10**
IV. sowing time	34,31	38,68	35,87	**36,29**
01 August 2003				
	PR38Y09	**PR37M34**	**PR36N70**	**average**
I. sowing time	29,30	35,96	31,20	**32,15**
II. sowing time	35,95	38,05	33,85	**35,95**
III. sowing time	31,24	31,47	38,96	**33,89**
IV. sowing time	37,75	42,95	37,87	**39,52**
27 August 2003				
	PR38Y09	**PR37M34**	**PR36N70**	**average**
I. sowing time	12,36	18,08	14,77	**15,07**
II. sowing time	13,36	17,16	16,94	**15,82**
III. sowing time	17,66	20,27	24,53	**20,82**
IV. sowing time	14,12	18,17	26,40	**19,56**

3.8. The effect of sowing time on the drying down dynamics of maize hybrids and on the seed moisture level at harvest time

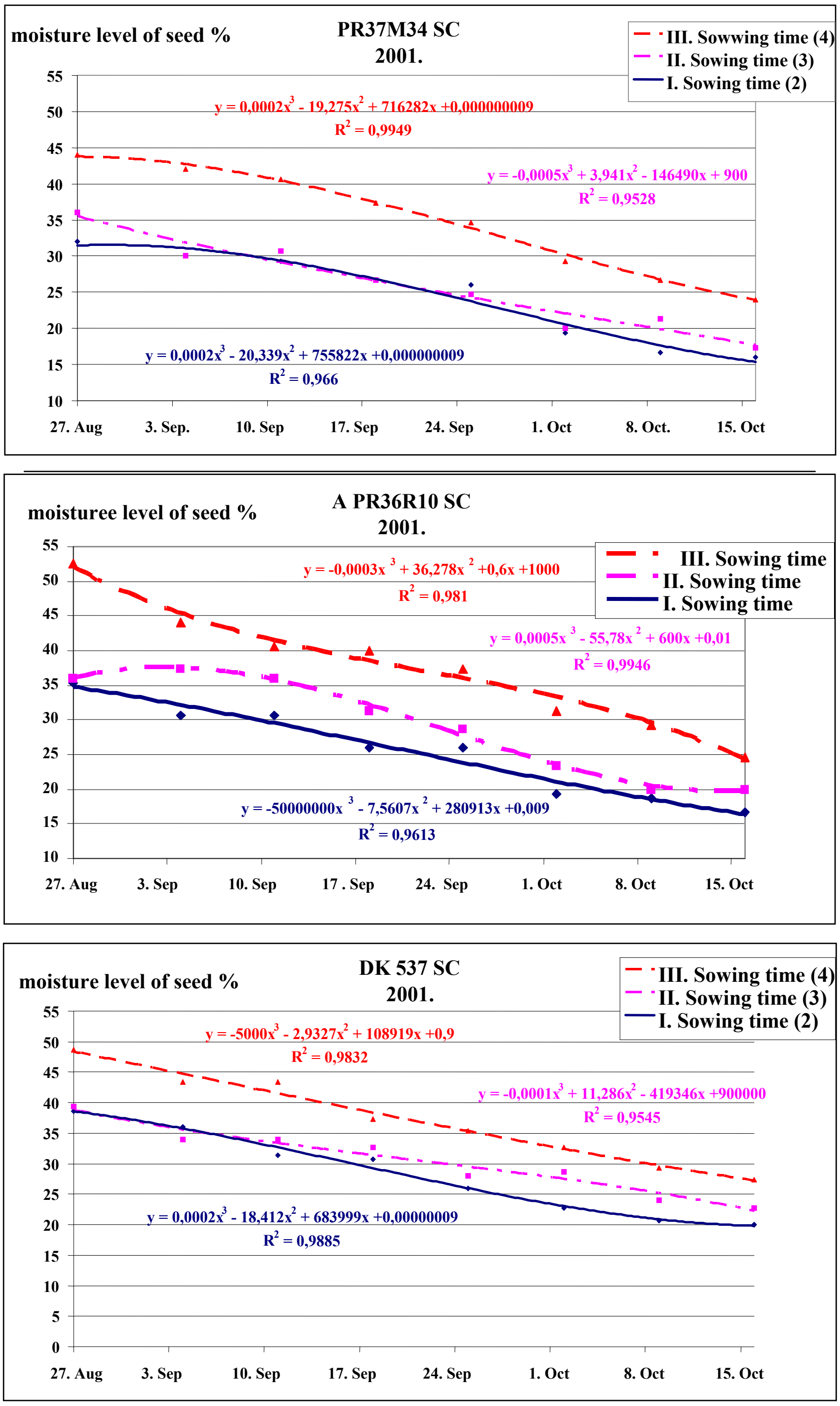
The analysis of drying down dynamics was carried out each year on several hybrids. Between the analyses, during August and October, we measured the seed moisture level seven-eight times. We can say that we found significant difference among all hybrids even at the first measure. This difference was especially big between early and late sowing. The difference between the first and the second sowing time was significantly smaller at the majority of hybrids. According to the statistical evaluation, there was provable significant difference between seed moisture levels at each time.

The difference of moisture level between hybrids was persistent till harvest, the values just got closer to each other at harvest time, however, they never became equal. There was 5-10 % moisture level difference between sowing times at harvest *(6. figure)*.

Hybrids with longer vegetation period are paired with higher seed moisture level at harvest. Therefore, despite of rainy weather, early mature hybrids (Sprinter) reached 20 % seed moisture level already by the middle of September. It means not only lower moisture level, but about 3-4 weeks earlier harvesting time in case of early sowing and on sowing at

20th April. This can mean that the autumn work peak gets longer, which is an important point of view regarding organizing work.

6. figure The drying down dynamics of maize hybrids in case of different sowing times



3.9. The correlation between yield forming elements and sowing time

Among yield forming elements, first we evaluated the number of rows and the number of seeds in one row. Both factor has a great impact on the individual performance of the maize plant, having effect on average yields as well.

Results show that the number of rows increased in all three years with later sowing and the difference was significant in each year.

The analysis of the number of rows was followed by the analysis of the number of seeds in one row. The length of corn-cob and the number of seeds in the rows have an influence on the individual performance of the plant, so it has impact on the average yield, too.

Each three year of the trial we experienced that there is a significant difference in the number of seeds as a result of different sowing times. In 2001 and 2002, the maize hybrids sowed at III. time increased the number of seeds, while the same significant growth occurred at II. sowing time in 2003.

Probably similarly to the formation of the number of rows, later sowing time provided more favourable environmental conditions to increased seed number. In 2003, the the III. sowing time would have resulted in big number of seeds, but because of the drought of the year, seeds situated at the end of the cob could not develop properly. We could see only the tiny seeds at the end of the cob.

This observation draws the attention to the not cleared correlation of the yield forming elements with different environmental factors (temperature, heat unit, the frequency of heat unit arrival, the quantity of precipitation, its dispersion).

We also analysed the different thousand seed mass values at different sowing times. We found significant variations between thousand mass values as well, however, this factor showed the highest value in 2001-2002 at the II. sowing time. III. sowing time provided the smallest value. Its reason is probably the following: under favourable environmental conditions more rows were formed, and in the rows there were more seeds. The size of the seeds however got smaller because of this condition. In 2003, II. sowing time provided the biggest thousand seed mass value, which was the result of smaller seed number per row.

3.10. The effect of sowing time on the performance of maize hybrids

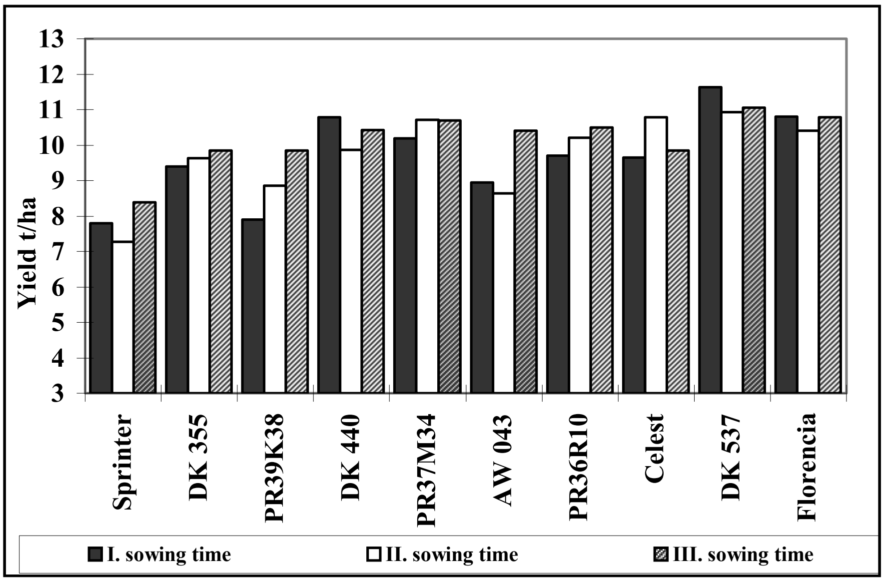
In 2001, the statistical evaluation of hybrids carried out with two-factor variant analysis, showed that there is significant difference only among hybrids. In 2001, the late sowed hybrids had the highest average yield (10,78 t/ha). Compared to this, we did not observe significant decrease in the average yield of hybrids sowed at optimal and late time. $LSD_{5\%}$ value: 0,92 *(17. table)*.

17. table The yields of maize hybrids sowed at different time, 2001.

Sowing time	yield t/ha	$LSD_{5\%}$
1.	9,679	**0,92**
2.	9,730	
3.	10,178	

In 2001, the yield of the analysed hybrids was good. It varied between 7,27-11,64 t/ha, depending on the vegetation period of the hybrids *(19. chart)*. That year, the rainfall of June and July got close to 100 mm, which allowed hybrids of different maturing time to behave in a different way.

7. figure. The yield of maize hybrids in different sowing time, 2001.

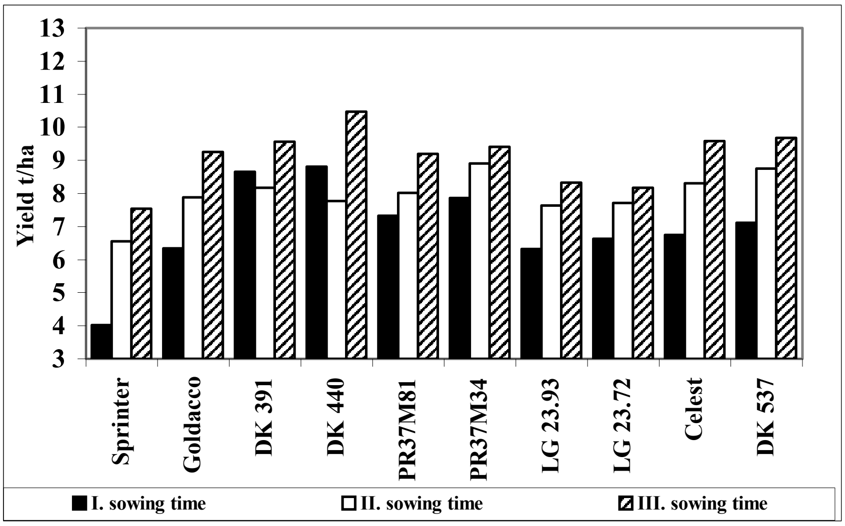


Among the evaluated hybrids, we can find ones that react less sensitive to sowing time (DK 440, PR37M34, Florencia) and there are hybrids that result in less yield if sowing time is not optimal (PR39K38, AW 043, Celest).

In 2002, the yield of the evaluated maize hybrids was at medium level. This means that hybrids reached 4,02-10,47 t/ha yield, depending on vegetation time.*(8. figure)*.

According to the data of the variant analysis, there was significant difference between both sowing time and hybrids. In 2002, there was significant difference between hybrids sowed at optimal time and early time *(18. table)*. $LSD_{5\%}$ value: 0,64.

8. figure. The yield of maize hybrids at different sowing times

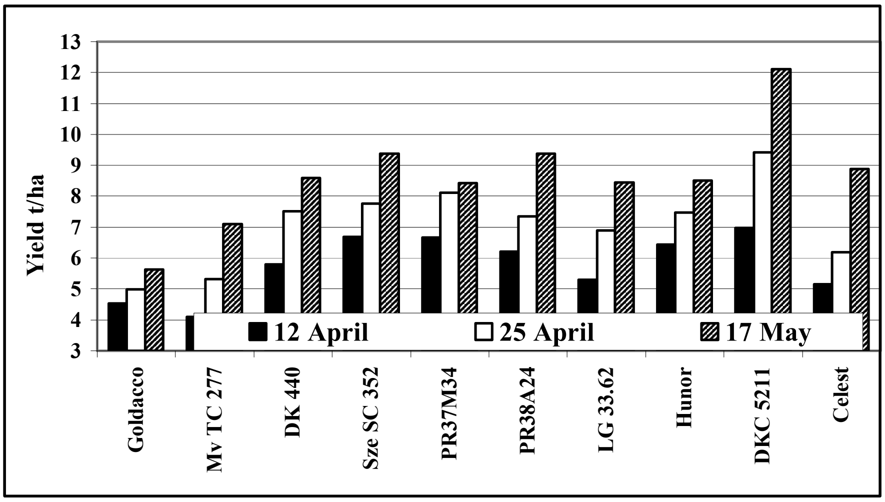


18. table. The yield results of maize hybrids at different sowing times, 2002.

Sowing time	Yield t/ha	$LSD_{5\%}$
1.	6,994	**0,64**
2.	7,996	
3.	9,235	

In 2003, all hybrids had the highest yield at 17th May sowing time *(9. figure)*. Similar to the experience of 2002, this result came because of rainfall dispersion which can seriously modify the performance of hybrids at different sowing times.

9. figure. The effect of sowing time on the yield of maize hybrids, 2003



In 2003, we found significant difference between each sowing time. The yield of the first sowing time was 5,783 t/ha in the average of the hybrids, second sowing time resulted in 7,100 t/ha, third sowing time had 8,65 t/ha. Each of them is significant, value of significant difference was 0,74 between sowing times in 2003.

As a result of the three year long trial, we can say that the yield of the maize, the quality of the yield and all the factors which form these results, are all extraordinarly influenced by nutrient supply and sowing time.

In all the three years we experienced significant changes regarding both average yield and quality. As a result of our analysis, we could observe the correlation of several yield forming elements with the yield. We also evaluated the effect of nutrient supply and sowing time on these yield forming elements.

We also measured the change of leaf area and photosynthetic activity in plots with different nutrient supply and different sowing time. We also determined how nutrient supply effects the quantity of yield by changing the leaf area and by influencing the photosynthetic activity. We also observed the similar changes causing effect of sowing time on the photosynthesis of maize hybrids.

We emphasized the changes caused by nutrient supply and sowing time, beginning from leaf area to the quality of the yield. We also explored those difficult correlations, which together form the results of profitable maize production.

4. New and up-to-date scientific results

1. There is a close correlation between the leaf area index (LAI) and the nutrient supply of maize hybrids. Nutrient supply significantly increases the leaf area index of hybrids, which results in bigger photosinthetically active leaf area. Therefore, there is close correlation between nutrient supply and leaf area index (LAI). The calculated r-values were between 0,887-0,992 in each year.
2. Nutrient supply has an effect on the photosinthetical activity of maize. The photosynthetic activity of aging plants on plots with good nutrient supply will decrease less than of plants on plots without fertilization. The photosynthetic activity of plots without fertilization is only 40-50 % of those plots, which received fertilizer. Water defficiency can significantly reduce the photosynthetic activity, even by 70 %. In case of water defficiency, maize will close stomas.
3. The nutrient exploring capacity and nutrient utilizing capacity of the modern hybrids have improved significantly. These hybrids reached maximum yields already at N_{40-80}, $P_2O_{5\ 25-50}$ és $K_2O_{\ 30-60}$ kg/ha, like PR37M81, Florencia and DK 557. We can grow these hybrids under extensive conditions as well for their excellent natural nutrient exploring capacity.
4. From the yield forming elements, thousand seed mass and the number of seeds had the closest correlation with the quantity of yield. So in case of maize, improving nutrient supply manifests most in the increase of thousand seed mass and the number of seeds. Optimal nutrient supply results in significant increase of thousand seed mass, number of rows and seeds on the cob compared to control.
5. The springing of early sowed maize hybrids is too long, it can be 15-20 days. Hovewer, germs of hybrids with good Cold-value will not die, because there was no provable difference in the number of growing individual plants. The vegetative period of the late sowed maize is by 18-23 days shorter. Its reason is the quickly accumulated heat unit, which causes fast development. This can result in stress situation.
6. The flowering of maize, which were sowed hybrids 30-35 days earlier, occur 12-15 days earlier, which can be an important factor in the protection of dry areas that tend to have drought.
7. There was a significant difference in the drying down capacity of hybrids sowed at different times for we received each time significantly lower seed moisture level at early sowing. Earlier sowing results in earlier maturing, faster drying down and 6-10 % less

seed moisture level at harvest. Therefore, earlier harvest and more efficient maize production becomes possible.

8. Nor nutrient supply nor sowing time had significant effect on the rate of seed dropout of maize hybrids seeds. It shows that the rate of droput is a genetic trait that is given to a hybrid.
9. Sowing time does not modify yield forming elements directly, but it changes through the effects of different environmental factors. In our analyses, each yield forming element had only weak correlation with the quantity of yield. Therefore, the effect of sowing time on the yield forming elements is small.
10. Among the analyzed, we found hybrids sensitive to sowing time (AW 043, Celest) and hybrids less sensitive to sowing time (PR36R10, DK537, Florencia). At sowing, we have to pay attention to this factor, it is necessary to use hybrid –specific technology.
11. We found significant differences in the quality of maize hybrids sowed at different times, hovewer, this is the result rather of the different environmental conditions at different sowing time and the result of average yields. Obvious change in the inner content was not proved.

5. Results that can be used in practice

1. The evaluation of leaf area index of maize hybrids provides such data that can be directly used for yield estimation, yield modelling. LAI makes early estimation possible
2. Being aware of the individual reactions of hybrids, we can develop the hybrid-specific technology in practice. This can improve competitiveness and ensure the protection of environment.
3. The yield capacity, nutrient exploring- and utilizing capacity of the analysed hybrids can be used directly in practice.
4. The effect of nutrient supply to the quality is very important in practice. Besides yield quantity, quality is becoming more important in maize production. In case of animal feed, the protein level of the maize is important. In case of isosugar or bioetanol production, starch content is the most important parameter.
5. The seed moisture level of maize hybrids at harvest depends largely on the nutrient supply and sowing time. The drying down rate of hybrids and the different drying down capacities, which were all shown under different treatments, can improve the efficiency of maize production.
6. The knowledge of specific reaction of maize hybrids at different sowing times is the basis of the creation of hybrid-specific technologies. Hybrids with wide flexibility to different sowing times and hybrids that have good reaction to nutrients should have an advantage in use.
7. The results of the three-year long trial can be used on areas with similar ecological character, and the results have practical side, too.

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