PhD thesis

EXAMINATION OF SEVERAL DETERMINANT AGRO-TECHNICAL FACTORS IN THE POINT OF VIEW THE YIELD SECURITY OF MAIZE

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INTRODUCTION, PRELUDE OF RESEARCH

Maize is one of the most important plants of the world. It plays an important role in human nutrition and animal feeding and its industrial use is also increasing. The maize production has almost reached 800 million tons in the last few years (Source: USDA).

In Hungary besides wheat, maize is the most important commodity; the crop area of these accounts for 1-1.2 million hectares. Depending on the weather conditions the maize yields – and consequently also the total production – fluctuate significantly. In Hungary the relative deviation of the yields to France (7.91%), to Germany (11.07%) and to Italy (8.1%) are 2-4 times larger, 25.65%.

In average condition the maize production of Hungary exceeds significantly the demand of the country. The export has an important role in channelling the oversupply. However, the fluctuating production has a significant effect on the external market sales. By ensuring stable yields the production can become calculable, which may provide protection from the potential strengthening of the market extremes.

The volume of fertilizers used in Hungary changed considerably during the last half century. Parallel to the professional and technological development a more conscious use of the nutrients was applied. Till the middle of the eighties, as a result of the large and high-level fertilizer supply the soil was filled with nutrients and the average maize yield increased in an incomparable pace reaching 6 t/ha. Since the beginning of the nineties because of the increasing fertilizer prices and low producer prices the applied amount of active agents fell drastic to 30-40 kg/ha. It has also an effect on yields, which could be observed on the fluctuation of yield security and production depending on year affect. Regarding the plant nutrition it is important to apply macro- and microelements regularly and in a harmonic way, since this encourages the yield security and hardiness.

The proper sowing time ensures higher yields and lower drying costs through the enhancement of yield security, faster water loss dynamics and lower seed moisture content at harvest. We have to keep in mind that amid the global warming up the frequency of extreme weather conditions is increasing and it appears in various forms (ice, storms, alternation of drought and rainy seasons). The early but at least optimal sowing time has a great number of advantages. The crop sown early grows faster and it is stronger, more resistant against the extreme dry spring and summer time, thus the yield security is higher. The benefit of faster development can also be observed at harvest: the lower seed moisture content at harvest the less drying cost, and the production will be more rentable.

The plant density affects yields and yield security also cardinally. In the last few decades, researchers have shown that maize tolerates the dense crop, which effects yields beneficially. Increasing of plant density shows a close correlation with the growing yields. But after a point plant density has a depressive effect on the production per hectare.

In the favour of increasing yield security and efficiency the professionalism is a very important factor, i.e., the ability to decide under given ecological and economical conditions what kind of agro-techniques have to be applied to reach the most favourable production and quality of yield by ecological production.

RESEARCH OBJECTIVES

The objective of the experiments was to study and analyse the opportunities of increasing yield and yield security, to develop a hybrid-specific production technology at a special cultivation area, to evaluate the relationships among various NPK nutrient doses, sowing time, plant density and yield as well as quality. It was a further goal to specialize the effects of leaf area index and photosynthetic activity on yields by various plant nutritions, sowing times and plant densities, as well as to increase the efficiency of maize production.

MATERIALS AND METHODS

The experiments were carried out in 2005, 2006 and 2007 in Debrecen at the Experimental Station of the University of Debrecen Centre of Agricultural Sciences and Engineering, Institute of Crop Sciences on calciferous chernozem soil. In my thesis I analysed the effect of some agro-technical elements, such as the use of fertilizers, the plant density and the effect of the sowing time in the cases of six different maize hybrids of various genetics and growing seasons. I evaluated the effect of the various factors on the leaf area, on the photosynthesis (plant density), the parameters of the main quality components (fertilizers, sowing date) and on the development of the production. The experiments were repeated three times (sowing date) and four times (fertilizers, plant number) in random blocks.

1. Weather of the experimental years

In 2005 the weather was extremely wet. In the growing season of maize the rain was by 152.2 mm more than the 30 years' average (*Table 1*). Owing to the rainy August and September, the development and maturation time of plants was delayed. The temperature did not deviate significantly from the 30 years' average. In 2005, the soil temperature in April and May the warming tendency was interrupted by short or long cool periods. The warming was hampered by the declining temperature on 11-12th April (10-11°C) and then on 21-22nd May (8-9°C). In the first decade of May the soil temperature fell from 21°C under 14°C in one week, which repeated between 16-20th of May.

Table 1: The amount of precipitation and the average temperature, Debrecen (2005-2007)

	Quantity of precipitation (mm)				Average temperature (^{o}C)			
	2005	2006	2007	30 years' average (1968-1997)	2005	2006	2007	30 years' average (1968-1997)
I.	5.0	26.5	14.0	37.0	-0.9	-3.4	3.7	-2.6
II.	40.5	67.7	58.1	30.2	-3.7	-1.4	4.1	0.2
III.	12.0	65.0	14.3	33.5	2.2	3.2	9.1	5.0
IV.	96.0	92.5	0.0	42.4	10.8	12.1	12.6	10.7
V.	59.2	66.7	52.6	58.8	16.2	15.4	18.4	15.8
VI.	52.0	71.6	16.7	79.5	18.4	18.6	22.2	18.7
VII.	89.5	34.9	70.0	65.7	21.1	23.2	23.3	20.3
VIII.	135.1	75.7	42.4	60.7	19.7	19.0	22.3	19.6
IX.	65.5	6.0	83.0	38.0	16.5	17.0	14.0	15.8
Total/Average	***554.8***	***506.6***	***351.1***	***445.8***	***11.1***	***11.5***	***14.4***	***11.5***
Differences from 30 years' average	109.0	60.8	-94.7	-	0.4	0.2	2.9	-
Breeding season (IV-IX.)	***497.3***	***347.4***	***264.7***	***345.1***	***17.1***	***17.6***	***18.8***	***16.8***
Differences from 30 years' average (IV-IX.)	152.2	2.3	-80.4	-	0.3	0.7	2.0	-

In 2006 in the growing season of maize (April-September) the rain was of 347.4 mm, which is only by 2 mm more that the 30 years' average. Its distribution in the growing season was favourable. The hail on 22 July damaged the assimilating surface of the plants significantly and it affected also the yields. The weather was favourable in September for water loss dynamics. The crop tolerated the heat in July relatively well. In the first half of April in 2006, the soil temperature fluctuated between 6-12°C, which increased in the second half of the month continuously. At the end of April it reached

20°C establishing favourable developmental chances for plants sown in April. Soil temperature decreased till the end of May to less than 14°C, which was disadvantageous for the growth, and the development of plants sown in May.

In 2007 we had to face a significant drought. The rainfall in the growing season of maize was 265 mm, which is by 80 mm down to year-long averages. As for the temperature it was an extraordinary year. Following a rather temperate winter the average temperature was significantly higher (by 2-3 °C) until September than the year-long averages. In the period of the formation of the yield, graining (July-August) the permanent heat (>25^{o}C) caused for maize a high stress effect. Soil temperature reached 12°C early in April. After this a continuously increase can be observed until the end of April. In the second half of May, the soil temperature decreased considerably, which affected the plants sown in May negatively.

2. Soil of the experimental area

The soil of the experiments was calciferous chernozem soil. It is characterized by the accumulation of humus compounds and it can easily be cultivated. There is no lime in the upper soil level, that is why the soil cracks in dry periods. The nutrient content of the soil is medium (N: 0,12%; AL-soluble P_2O_5: 100 mg/kg; K_2O: 165 mg/kg), the nutrient dynamics is good, the content of organic matter is 2,7%. The humus depth of level „A" is 50-70 cm. The plasticity index according Arany was 45, the pH value 7,0 (H_2O).

3. Agro techniques applied in the experiments

The main agro-technical data are resumed in *Tables 2-4*. In 2005, at third late sowing there was a great absence of plants, that is why we cannot evaluate the results of this treatment reliably.

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Table 2: Data of agro techniques in fertilizer experiments

	2005	2006	2007
Soil preparation	17 Nov. 2004 plough 8 April 2005 prepare of seed-bed	26 Oct. 2005 plough 18 April 2006 prepare of seed-bed	20 Oct. 2006 plough 28 March 2007 prepare of seed-bed
Applied fertilizer doses	control (without fertilization) treatment 1. treatment: 40 kg/ha N, 25 kg/ha P_2O_5, 30 kg/ha K_2O active agent 2. treatment: 80 kg/ha N, 50 kg/ha P_2O_5, 60 kg/ha K_2O active agent 3. treatment: 120 kg/ha N, 75 kg/ha P_2O_5, 90 kg/ha K_2O active agent 4. treatment: 160 kg/ha N, 100 kg/ha P_2O_5, 120 kg/ha K_2O active agent 5. treatment: 200 kg/ha N, 125 kg/ha P_2O_5, 150 kg/ha K_2O active agent		
Plant density	FAO 200-300: 79 thousand plants/ha (Szegedi 269, DK 440, PR37D25) FAO 400-500: 71 thousand plants /ha (NK Cisko, Mv Maraton, PR34B97/PR36K67)		
Sowing date	1-3 May	26 April	19-20 April
Emergence date	14 May	8-10 May	5 May
Plant protection	soil infection: 15 April weed control: 31 May	soil infection: 18 April weed control: 29 May	soil infection: 16 April weed control: 10 April
Harvest	12-13 October	13 October	28 September

Table 3: Data of agro techniques in sowing time experiments

	2005	2006	2007
Soil preparation	17 Nov. 2004 plough 8 April 2005 prepare of seed-bed	27 Oct. 2005 plough 9 April 2006 prepare of seed-bed	20 Oct. 2006 plough 28 March 2007 prepare of seed-bed
Nutrient supply	130 kg/ha N, 90 kg/ha P_2O_5, 110 kg/ha K_2O active agent		
Plant density	FAO 200-300: 79 thousand plants/ha (Szegedi 269, DK 440, PR37D25) FAO 400-500: 71 thousand plants /ha (NK Cisko, Mv Maraton, PR34B97/PR36K67)		
Sowing date	Sowing date I: 8 April Sowing date II: 25 April Sowing date III: 2 June	Sowing date I: 10 April Sowing date II: 24 April Sowing date III: 15 May	Sowing date I: 10 April Sowing date II: 25 April Sowing date III: 16 May
Emergence date in the order of sowing date	23 April 5 May 14 June	28-29 April 4 May 23-24 May	21 April 6 May 31 May
Plant protection	weed control: 31 May, 28 July	weed control: 29 May	weed control: 10 June
Harvest	25 October	11 October	28 September

Table 4: Data of agro techniques in plant density experiments

	2005	2006	2007
Soil preparation	17 Nov. 2004 plough 28 April 2005 prepare of seed-bed	26 Oct. 2005 plough 18 April 2006 prepare of seed-bed	20 Oct. 2006 plough 28 March 2007 prepare of seed-bed
Nutrient supply	130 kg/ha N, 90 kg/ha P_2O_5, 110 kg/ha K_2O active agent		
Plant density	45 000 plants/ha, 60 000 plants /ha, 75 000 plants /ha, 90 000 plants /ha		
Sowing date	3 May	26 April	16 April
Emergence date	16 May	8-10 May	28 April
Plant protection	soil infection: 15 April weed control: 31 May	soil infection: 18 April weed control: 29 May	weed control: 10 June
Harvest	18 October	11 October	27 September

In 2005, the western corn root worm (*Diabrotica virgifera*) was in great strength present in the sowing date, plant density and fertilization experiments. It has seriously damaged the PR34B97 hybrid, there were many ears with only a few seeds. Therefore by the evaluation of yield results we left out this hybrid.

4. Maize hybrids involved in the experiments

In 2005 and 2006, we tested the same six hybrids with different maturation times and genetics. In 2007, because of the unlikely experiments of the two previous years, we had to change a hybrid. Instead of PR34B97 (FAO 590) with the longest maturation time the PR36K67 (FAO 490) hybrid was used in the experiments in that year.

Table 5: Maize hybrids involved in the experiments

2005	2006	2007
Szegedi 269 (FAO 304) DK 440 (FAO 320) PR37D25 (FAO 330) NK Cisko (FAO 430) Mv Maraton (FAO 450) PR34B97 (FAO 590)	Szegedi 269 (FAO 304) DK 440 (FAO 320) PR37D25 (FAO 330) NK Cisko (FAO 430) Mv Maraton (FAO 450) PR34B97 (FAO 590)	Szegedi 269 (FAO 304) DK 440 (FAO 320) PR37D25 (FAO 330) NK Cisko (FAO 430) Mv Maraton (FAO 450) PR36K67 (FAO 490)

5. Measures, examinations

In all the three experiments and in each of the three years, we measured the leaf area. We applied the Montgomery formula by hand measurements, in the other cases we used the LAI 2000 leaf area measurer.

We measured the photosynthetic activity in each of the three years in plant density experiments using LICOR 6400 mobile field photosynthesis measurer. The most important parameters fixed by the device were: photosynthesis (μmol $CO_2/m^2/sec$), openness of stomates (mol/m^2/sec), efficiency of CO_2-binding, intercellular CO_2-level (mmol/mol), transpiration (mmol/m^2/sec).

We observed the water loss dynamics of hybrids in the period of maturation, and also the seed moisture content at harvest. In order to analyse the water loss dynamics we carried out the measures weakly.

We evaluated from the quality parameters of the maize seed the protein, the oil and starch content in the chosen treatments (samples) of fertilization and sowing time experiments. Determination of the quality parameters was carried out in accordance with the Hungarian Standards. The colleagues of the Institute for Food Sciences, Quality Assurance and Microbiology, UD Centre for Agricultural Sciences and Engeneering helped to perform the laboratory tests.

RESULTS

1. Relationship between the tested agro-technical factors and the yield of maize

1.1. Relationship between the fertilization and the yield of maize, 2005-2007

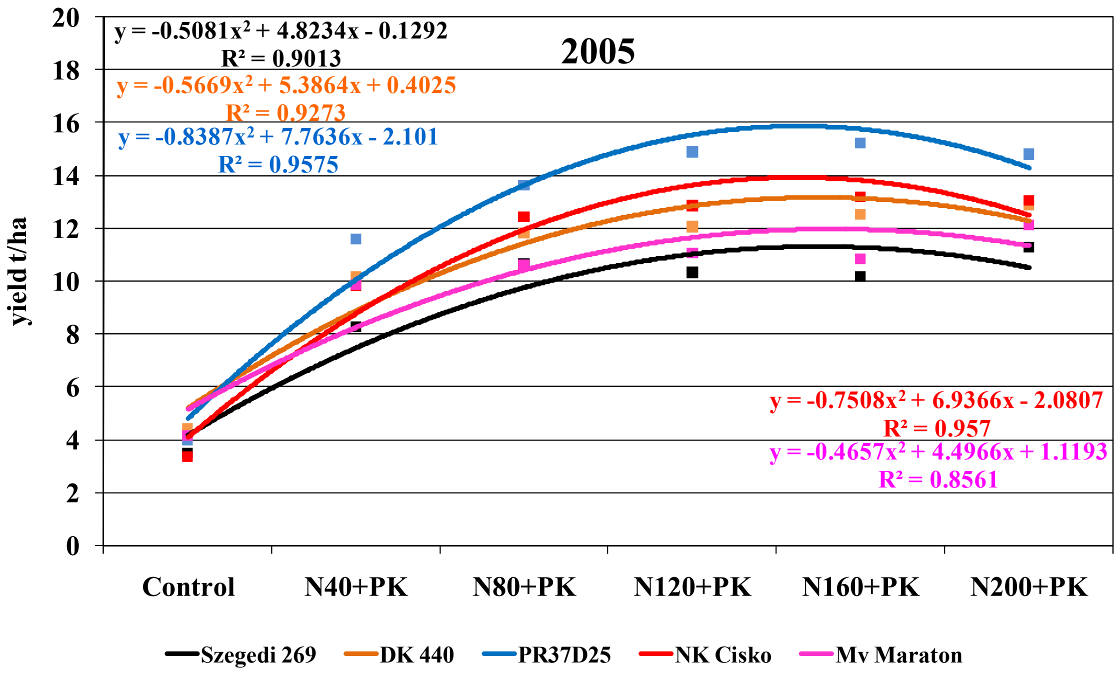


Figure 1: Effect of fertilization on the yield, 2005

The production of maize hybrids tested in 2005 in the control treatment, without the application of fertilizers fluctuated between 3.4-4.44 t/ha (*Figure 1*). The nutrition intake was the best of DK 440 and Mv Maraton. In Treatment 1 the yields of all the hybrids increased twofolds compared to the yields of the control fields. The yield increase was the largest in the case of PR37D25 (191%) indicating an excellent fertilizer reaction. The production of the hybrids increased up to Treatment 3-4 and then in the case of the largest doses decreasing trends can be seen. In the cases of all fertilizer levels the production of PR37D25 was the largest (11.8-15.22 t/ha). This was followed by NK Cisko, and DK 440.

In 2006 in the control field the lowest yield did hardly exceed 2 t/ha (Szegedi 269: 2.13 t/ha), while the maximum remained under 4 t/ha (NK Cisko: 3.62 t/ha). Owing to the wet weather conditions the fertilizers of increasing intensity had a positive effect however, the production did not reach the level of the previous year (*Figure 2*). Similar to 2005 the smallest doses of fertilizer increased the production the most; in the cases of Szegedi 269 and DK 440 the increase was of 100% (149%; 109%), compared to the control and also in the cases of the other hybrids by 50-100%. The production of the hybrids showed an increasing tendency up to fertilizer level 3 and then the effect decreased or did not change at all. The differences of the hybrids are not prevailing in this year. In 2006 the hybrids of best fertility were NK Cisko and DK 440. The result obtained by PR34B97 was also good. The production of Mv Maraton was the lowest.

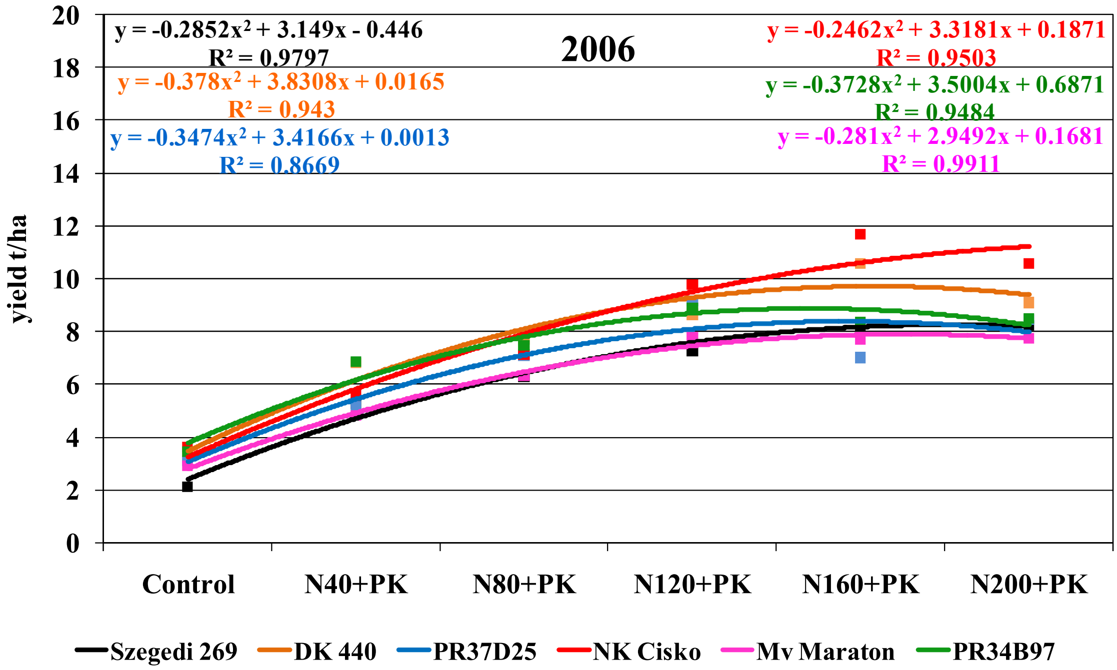


Figure 1: Effect of fertilization on the yield, 2006

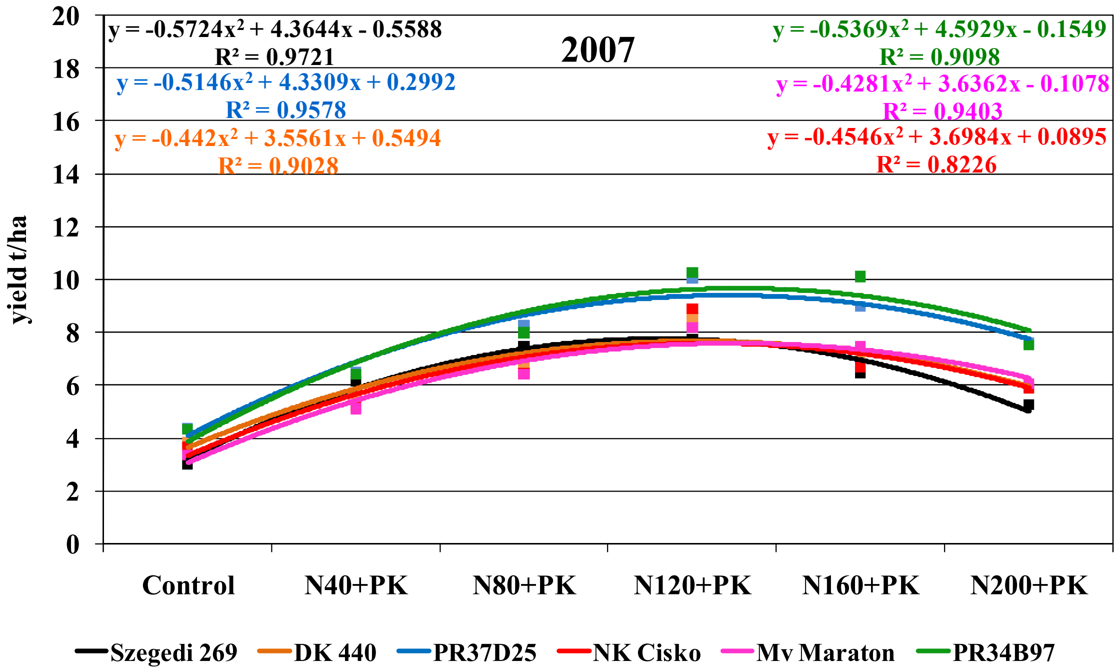


Figure 1: Effect of fertilization on the yield, 2007

In 2007 without fertilizers the production of the hybrids reached 3.03-4.39 t/ha (*Figure 3*). The production increased by various extent due to the smallest doses of nutritive supply. The production of Szegedi 269 has doubled and in the cases of the other hybrids the production increased by 40-50% compared to the parcels not treated by fertilizers. Owing to the dry weather conditions the smallest doses of fertilizers could not as much productive as in the previous years. By increasing the fertilizer doses the production increased significantly up to the 3rd level and then the yields decreased. The results of 2007 support the hypothesis, that is the increasing fertilizer doses increase the production only up to a certain level and fertilizer overdosing the production start to decrease. This phenomenon is in close relationship with the weather conditions of the given year; first of all with the fall and the utilisation of the fall and through this the mobility of the nutritive in the soil. The two Pioneer hybrids resulted the highest yields by each treatment.

Table 6: Statistical analysis

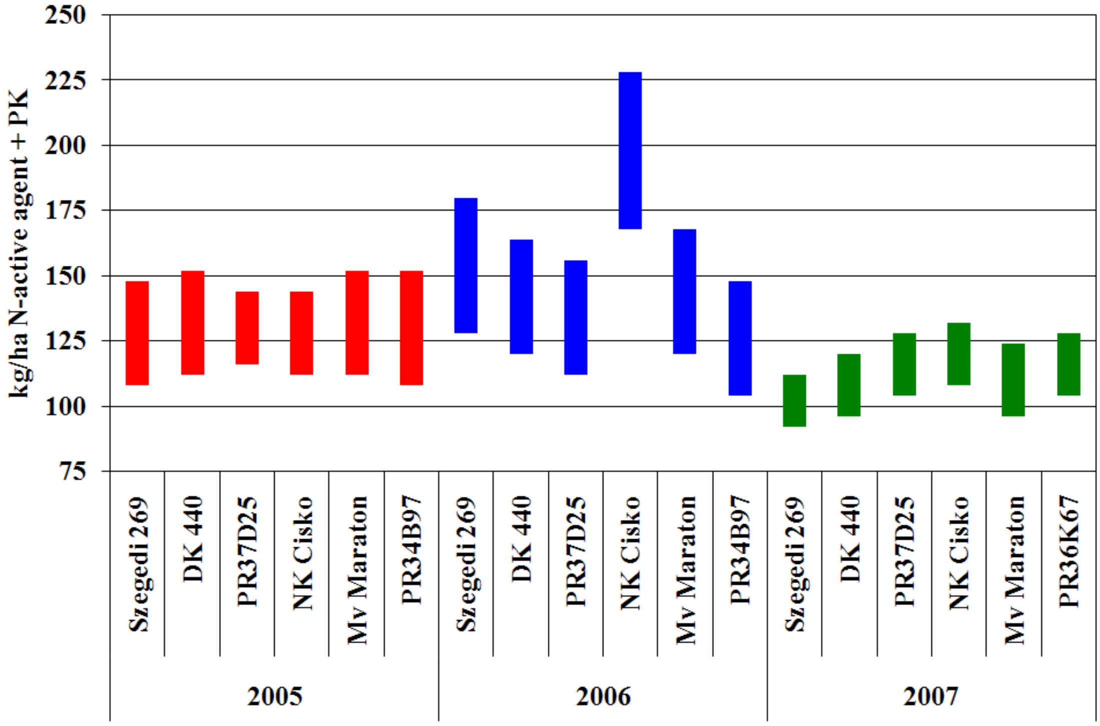
	2005	**2006**	**2007**
$SzD_{5\%}$ fertilization (t/ha)	**1.14**	**1.01**	**0.41**

r	**production**
fertilization	**0.556****
LAI	**0.584**-0.770****
precipitation July	**0.346****
precipitation August	**0.470****
temperature April	**-0.479****
temperature July	**-0.487****

By the help of the data of the yields and the values of $SzD_{5\%}$ we determined the optimal fertilizer requirement of the hybrids, the intervals of the fertilizer optimums (*Figure 4*). In 2005, when the fall was abundant there was no significant difference among the optimal fertilizer requirements of the six hybrids; by supplying 110-150 kg/ha N+PK active agent was sufficient to obtain maximal yields. Larger doses were not productive and they rather loaded the environment. The fertilizer optimums of Szegedi 269, DK 440 and Mv Maraton hybrids were favourably large.

In 2006 when the volume of the rainfall and its distribution during the production season was almost optimal, differences could be seen among the hybrids. The nutritive optimum required for obtaining maximum yields fluctuated by large intervals in the cases of all hybrids tested due to good absorbability and mobility. The results obtained are extending in the cases of NK Cikso indicating that the hybrid by optimal environmental conditions can absorb larger than usual doses of fertilizers. This is extremely important for unloading the environment. The early Szegedi 269 could favourable use large doses of fertilizers.

The year of 2007 was extremely dry; which was also reflected by the fertilizer optimums. The low water content of the soil, the difficult accession of the elements and the low level of mobility the optimal fertilizer interval of the hybrids tested was quite narrow and large doses could not be used. In droughty years the hybrids in general could increase their production by increasing the fertilizer doses up to 90-130 kg/ha N+PK active agent.



Figue 4: The optimum interval of fertilizer doses

1.2 Relationship between the sowing time and the yield of maize, 2005-2007

In 2005 the production of the hybrids in the second sowing time was significantly lower than in the first sowing time (*Figure 5*). The only exception is the hybrid of PR37D25 the development and production of which was influenced more favourable by the second sowing time to be considered as optimal. Regarding the seed moisture content at harvest time significant differences could be seen in the cases of Szegedi 269 and NK

Cisko hybrids, where due to the later sowing time the value increased. The moisture content of DK 440 and Mv Maraton hybrids increased by minimal extent.

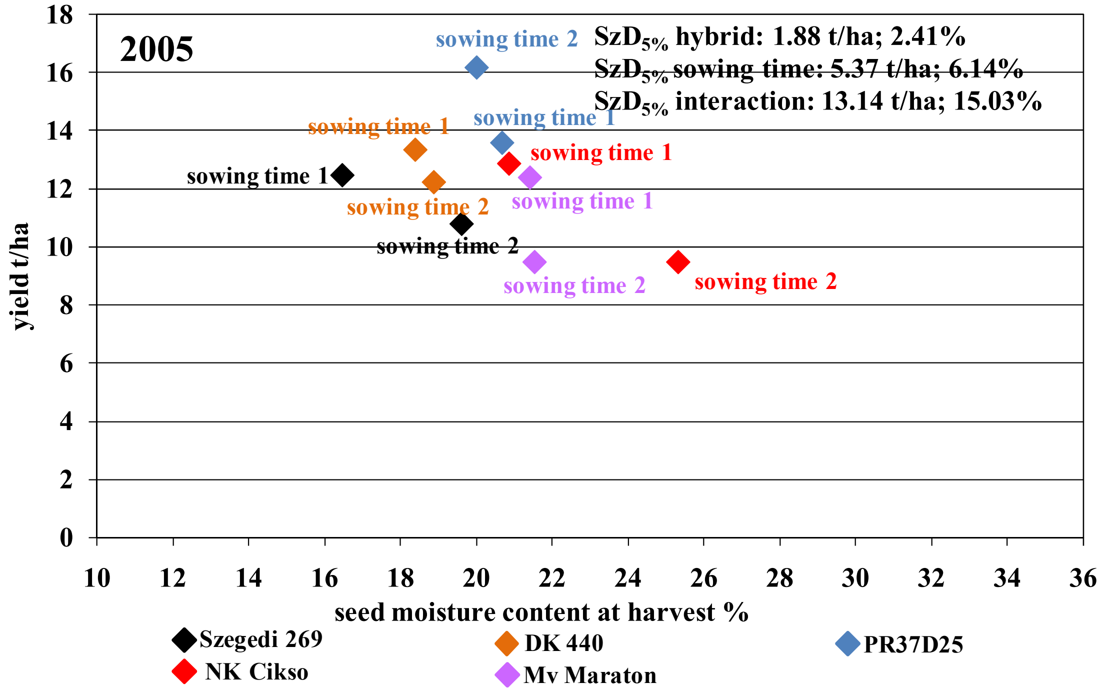


Figure 5: Effect of sowing time on the yield and seed moisture content at harvest of the hybrids, 2005

In 2006 the production of the hybrids was the lowest in the first sowing time (*Figure 6*). The decreased production of the hybrids was probably due to the hail of 22nd July since the development of these was more developed than the hybrids of later sowing time. By considering Szegedi 269, DK 440 and PR37D25 parallel to extending the sowing time the production increased continuously, while the production of NK Cisko and Mv Maraton of third sowing time decreased significantly. The moisture content at harvest time was the lowest at hybrids of early sowing time and it increased parallel to extending the sowing time.

Regarding both the seed moisture content and the production the unfavourable effect of the delayed sowing time can be seen in 2007 (*Figure 7*). Owing to the droughty year only those hybrids could properly develop which were sown in time and then there was still sufficient moisture in the soil for the initial development. The production of all the hybrids tested was the largest in the first sowing time and this decreased significantly by extending the sowing time. The development of the seed moisture content was of opposite direction, that is, delayed sowing time led to higher values.

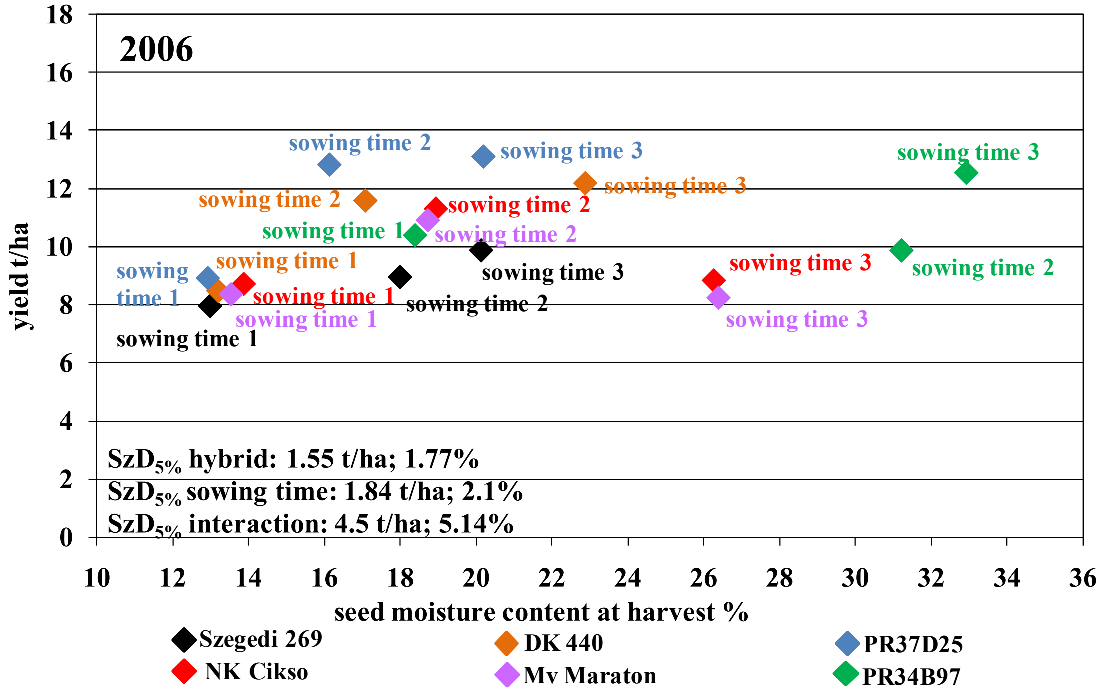


Figure 6: Effect of sowing time on the yield and seed moisture content at harvest of the hybrids, 2006

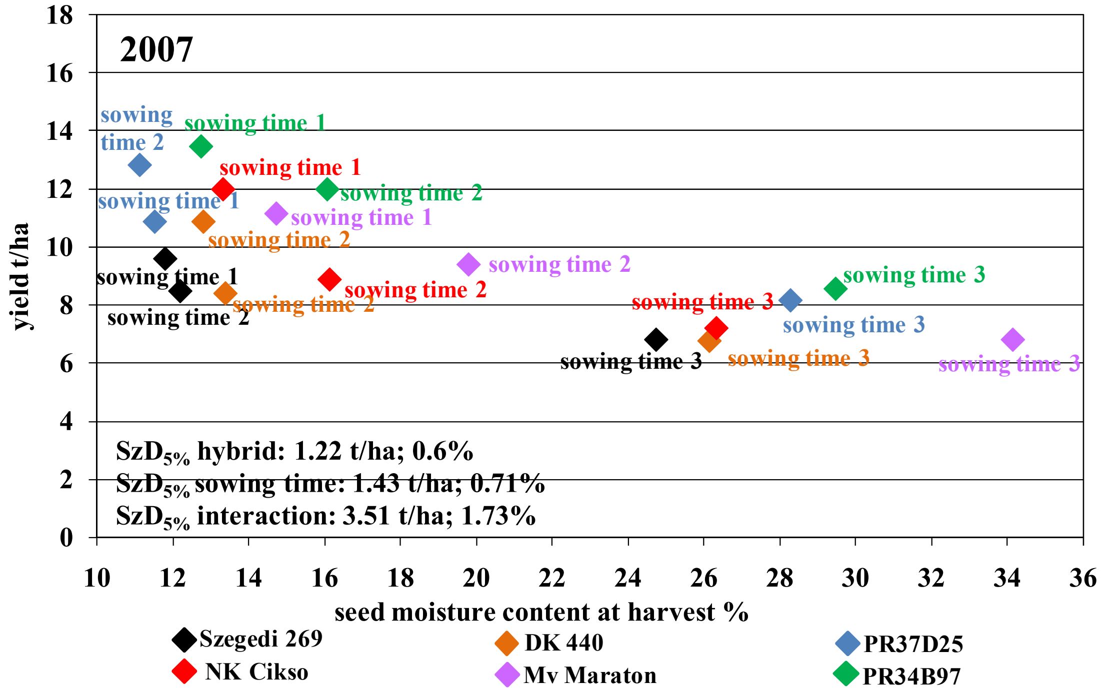


Figure 7: Effect of sowing time on the yield and seed moisture content at harvest of the hybrids, 2007

Table 7: Statistical analysis

r	seed moisture content at harvest	production
hybrid	**0.385****	**-**
sowing time	**0.666****	**-0.332****
precipitation April	**-**	**0.274****
precipitation July	**-**	**0.385****
precipitation August	**-**	**0.385****
temperature April	**-0.387****	**-**
temperature July	**-0.376****	**-**
temperature August	**-0.209***	**-**

1.3. Relationship between the plant density and the yield of maize, 2005-2007

As a result of the abundant fall in the productive period of 2005 the development of the plants was undisturbed even in the more dense fields. The proper nutrition and water supply ensured the easy and adequate access to the nutritive. By increasing the plant density the production of the hybrids increased significantly almost in all cases up to the highest plant density (*Figure 8*). The yields of most hybrids were the smallest at plant density of 45 thousand fluctuating between 8.55-11.79 t/ha. Maximum yield were obtained at each hybrid by the plant density of 90 thousand between 11.68-16.05 t/ha. The production of PR37D25 was outstanding in the cases of all densities. It was followed by NK Cisko, DK 440, Mv Maraton and Szegedi 269.

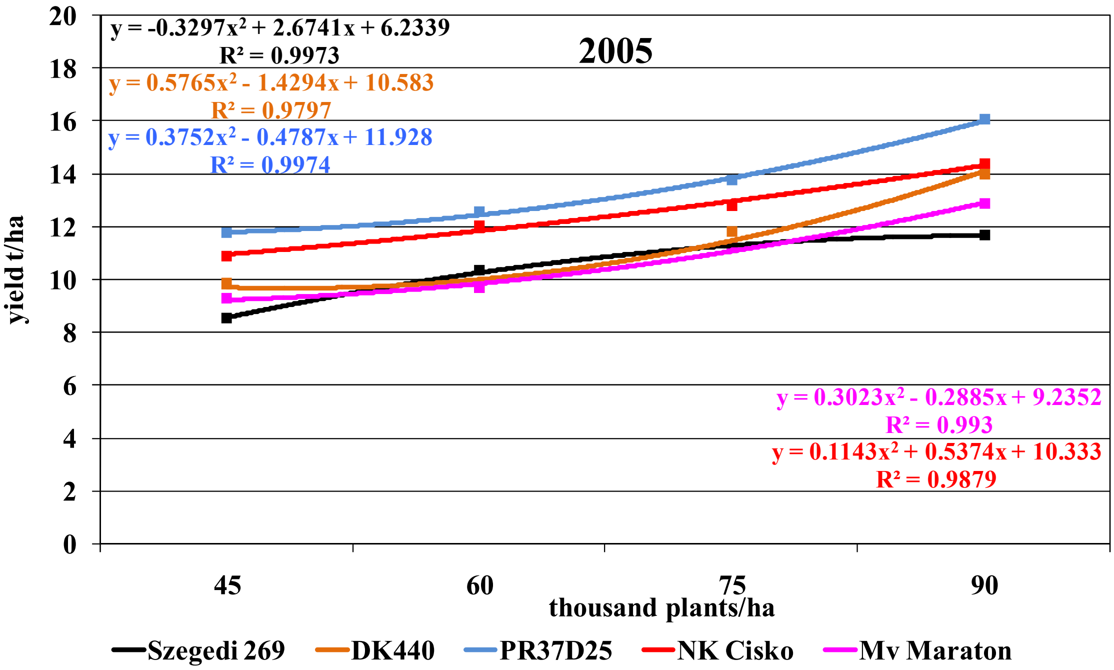


Figure 8: Effect of plant density on the yield, 2005

The production of the hybrids was less in 2006 than in the previous year (*Figure 9*). The best result was achieved by PR34B97 at a plant density of 60 thousand (9.81 t/ha). The production of Szegedi 269 was the smallest from all the treatments; it fluctuated between 5.83-7.61 t/ha. At Szegedi, Dekalb and PR37D25 hybrids the production increased significantly up to 75-90 thousand plant/ha but in the cases of NK Cisko and PR34B97 hybrids above 60 thousand plants/ha while in the case of Mv Maraton above 75 thousand plants/ha the production decreased significantly.

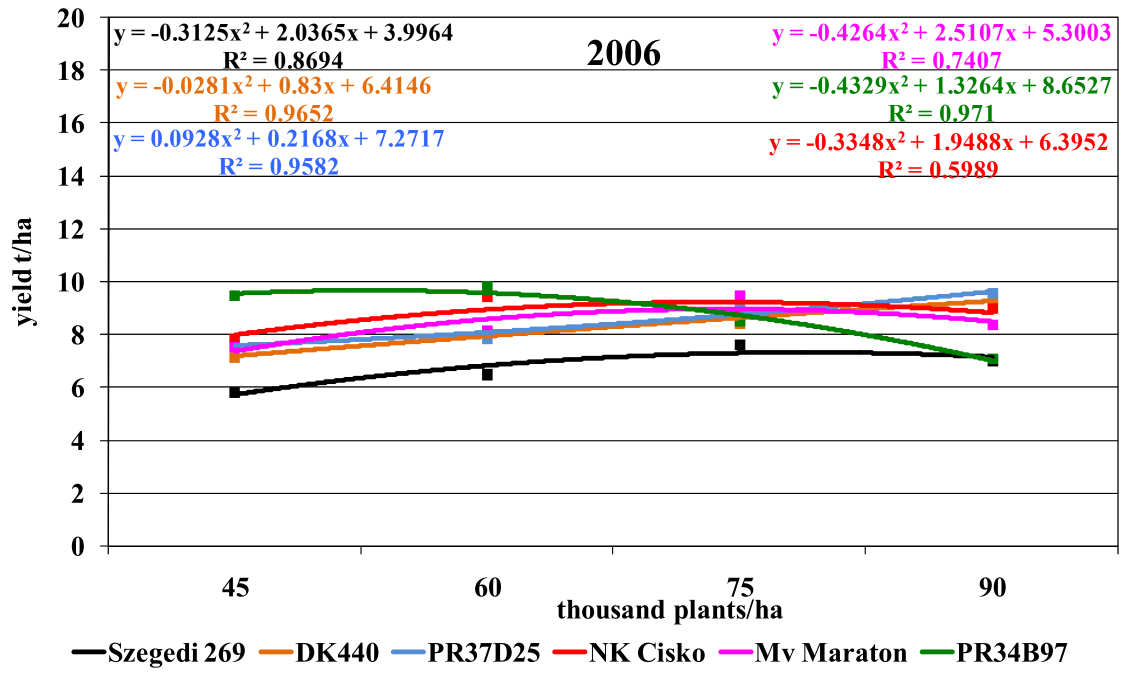


Figure 9: Effect of plant density on the yield, 2006

In spite of the droughty year some of the hybrids tested in 2007 reached outstanding results justifying its genetic stability and excellent adaptability to the extremely dry weather condition (*Figure 10*). Maximal yields were reached by PR37D25 at plant density of 75 thousand (12.96 t/ha). Similarly to the previous results the production of Szegedi 269 was the lowest in all treatments which is mainly due to the low potential productivity deriving from the early sowing. On the basis of the results obtained the dry weather tolerating capacity of the hybrids can also be followed. The production of the hybrids tested increased significantly in several cases up to 75 thousand plants/ha while in the case of 90 thousand plant density a decreasing trend can already be seen.

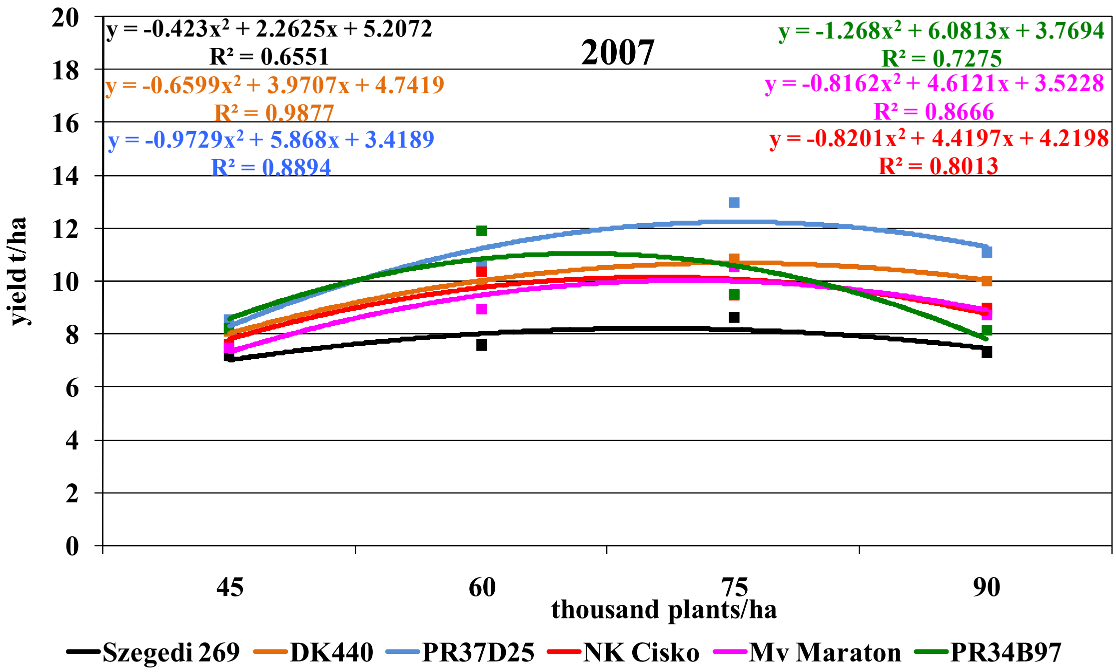


Figure 10: Effect of plant density on the yield, 2007

Table 8: Statistical analysis

	2005	2006	2007
$SzD_{5\%}$ plant density (t/ha)	**0.85**	**0.62**	**0.54**

r	**production**
plant density	**0.319****
LAI	**0.284*-0.515****
photosynthesis VII.	**-0.309***
precipitation July	**0.563****
precipitation August	**0.457****
temperature April	**-0.485****
temperature July	**-0.556****

On the basis of the yield per hectare and the $SzD_{5\%}$ values the interval of optimal plant density was determined during the three years of the tests (*Figure 11*). In 2005 the hybrids selected reacted to the increase of the plant density by production growth. However we have to state that in addition to the favourable rain fall supply and distribution optimal plant numbers have to be set 70-80 thousand/ha, which will ensure the security of the yields and in this way the plantation will be less sensitive to the extreme weather conditions.

In 2006 the difference among the hybrids could be seen. The optimum interval of Szegedi 269 was favourably wide, which proves its excellent adaptability. Good results were also achieved by PR34B97 and NK Cisko. In the case of Mv Maraton the interval was narrow and it established at a low plant density number. This proves that in an average year the application of high density is not necessary for reaching maximal yields.

In 2007 the optimal plant density was between 60-75 thousand plants/ha. Szegedi 269 tolerated the best the fluctuating plant number per hectare. In the cases of DK 440 and PR37D25 the interval was narrower; however the reaction to high plant numbers was still positive. NK Cisko and PR36K67 tolerated less the lack of water and the optimum interval was very narrow in this case. The fact that the yields at low densities are more secure is related to the long growing period of this latter hybrid. In 2007 for reaching maximum yields with Mv Maraton higher densities were more favourable, which indicates that due to the drought the individual production is lower.

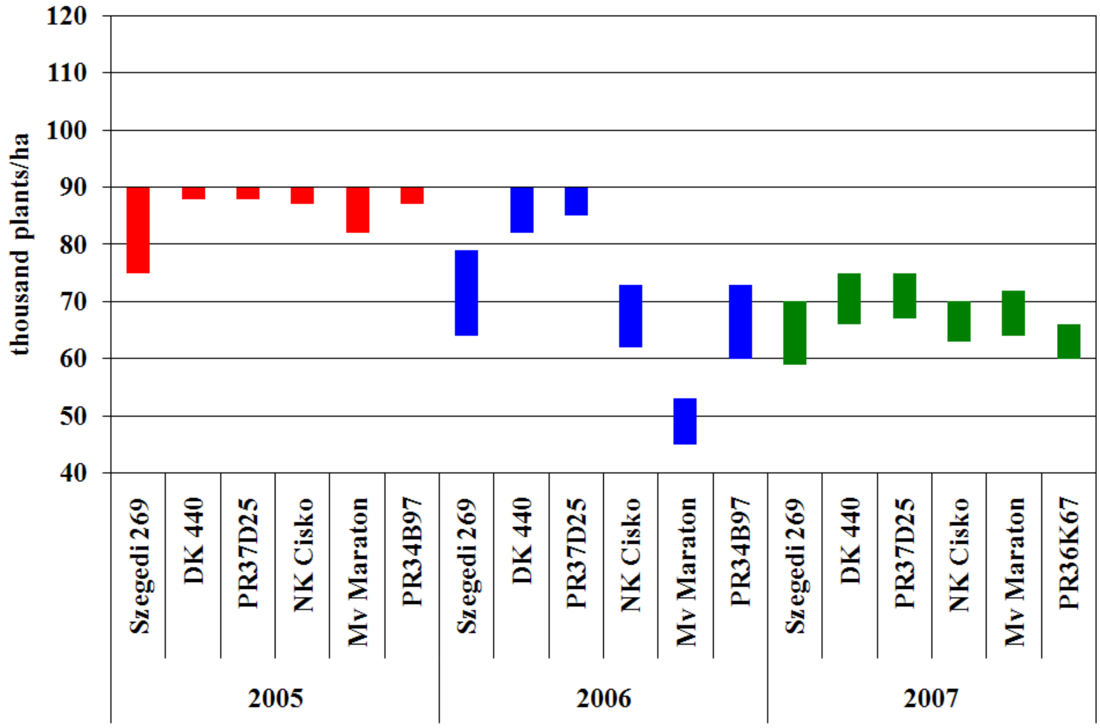


Figure 11: The optimum interval of plant density

2. Fluctuation of photosynthetic activity depending on plant density, 2005-2007

In tests of increasing the plant density the photosynthetic activity of the hybrids was also tested. In 2005 the photosynthesis of the 60 thousand plants/hectare plantation at Szegedi 269 was intensive during the vegetation period; the values measured were between 35-40 ηmol/CO_2/m^2/sec (*Figure 12*). On the contrary by advancing in the growing period at larger plant densities the photosynthesis decreased, which can be explained by water shortage of the dense plantations. In the case of ***PR34B97*** hybrid the photosynthesis activity at the density of 90 thousand was low in June, which was due to the very hot weather in June to the lacking rainfall and the closed stomates.

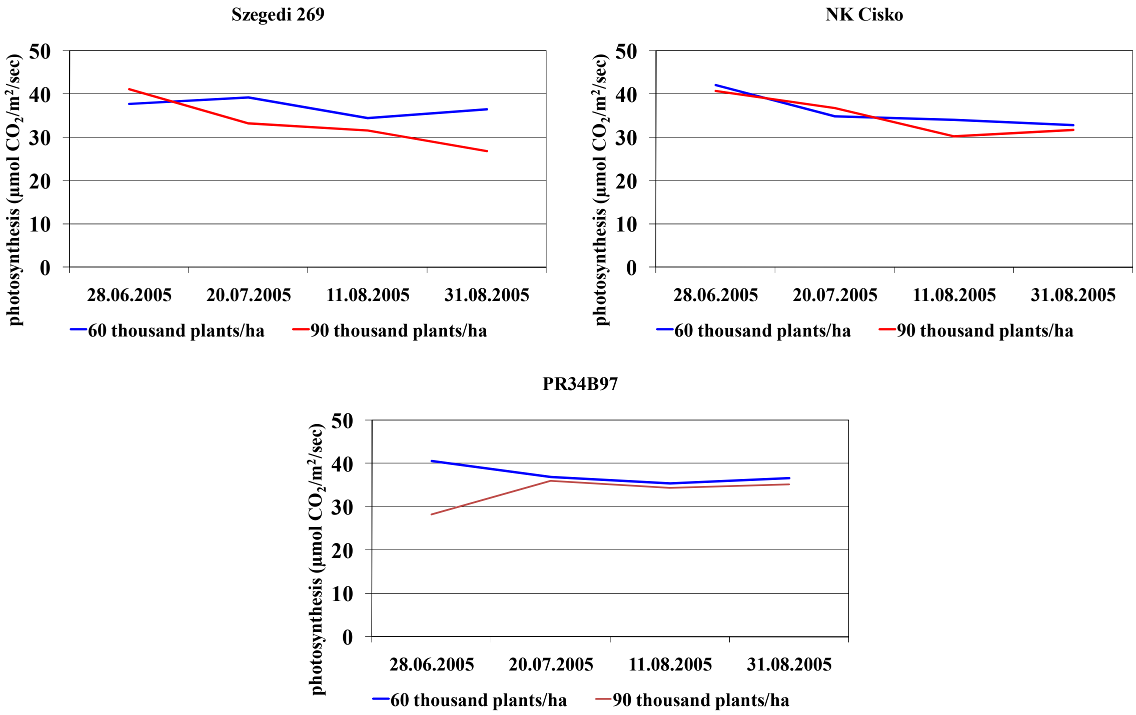


Figure 12: Effect of plant density on the photosynthesis of the hybrids, 2005

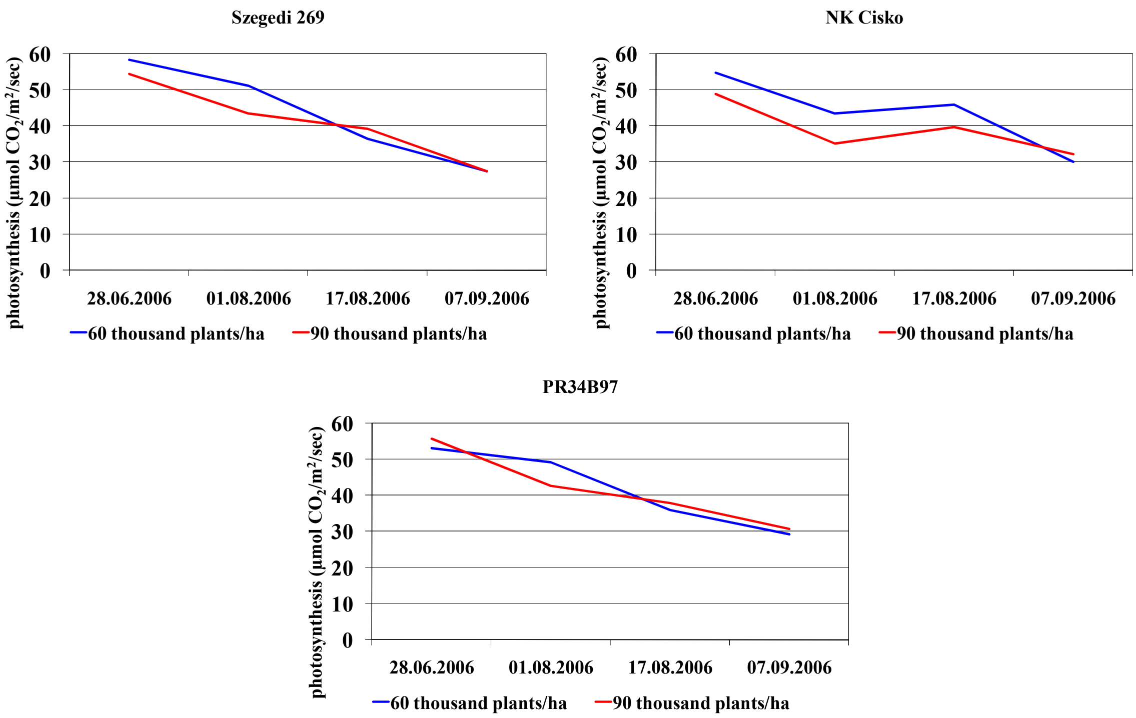


Figure 13: Effect of plant density on the photosynthesis of the hybrids, 2006

In 2006 the net photosynthesis of Szegedi 269 was the highest in the cases of both densities in June 55-60 ηmol/CO_2/m^2/sec (*Figure 13).* Owing to the hot and dry July the photosynthesis of the plants decreased. The photosynthetic activity of NK Cisko was also the highest in June and the photosynthesis of the plants was more intensive by the plant density of 60.000 thousand; plantations of higher densities were hit more by the lacking water supply.

The photosynthesis of the hybrids tested was rather hectic in 2007, which was mainly due to the weather conditions in the period of the measures and the effects of the season (*Figure 14*). The lacking water supply in June limited the development of the plants and also the photosynthesis.

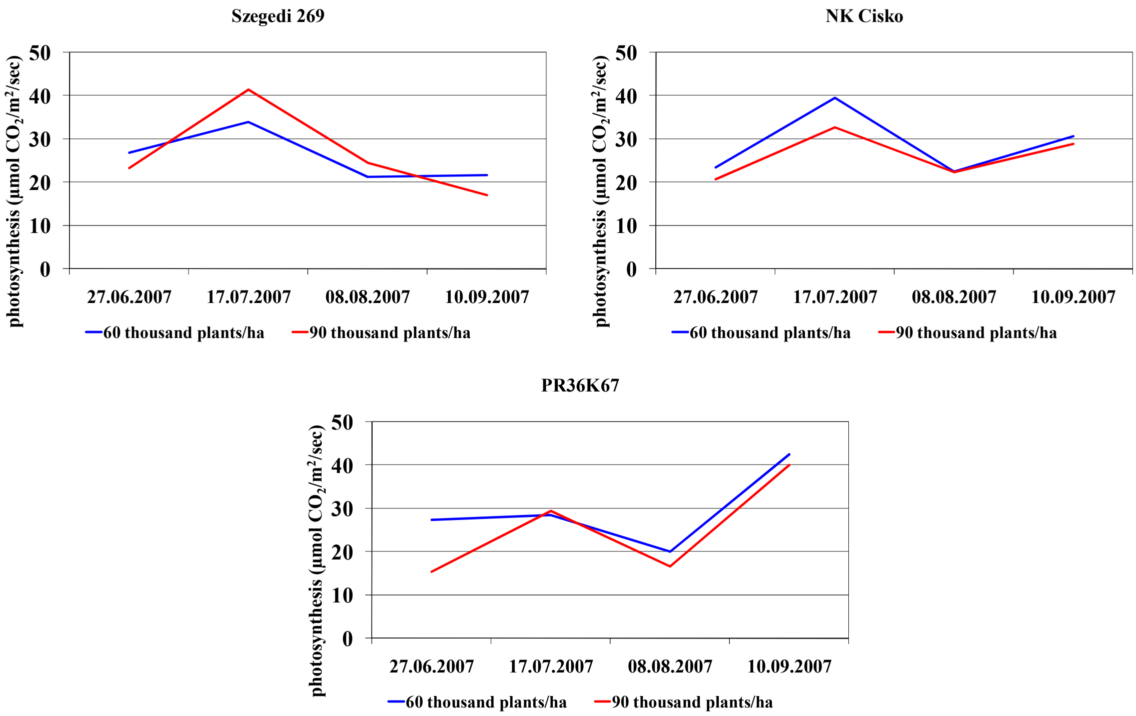


Figure 14: Effect of plant density on the photosynthesis of the hybrids, 2007

Table 9: Statistical analysis

r	photosynthesis June	photosynthesis July
hybrid	-	-
precipitation	0.885**	-0.442**
temperature	-0.754**	-

r	photosynthesis August	photosynthesis September
hybrid	-	-
precipitation	0.429**	-
temperature	-0.799**	-

3. Relationship between the tested agro-technical factors and the leaf area index, 2005-2007

The affect of the agro-technical factors on the leaf area in the growing season was different, which can be observed on the example of Szegedi 269 hybrid.

Owing to the more intensive fertilization the leaf area increased, but the effect of the doses were diverse (*Figure 15*). The application of 200 kg/ha N+PK active agent caused in several cases higher LAI, moreover in some cases it decreased at the largest dose.

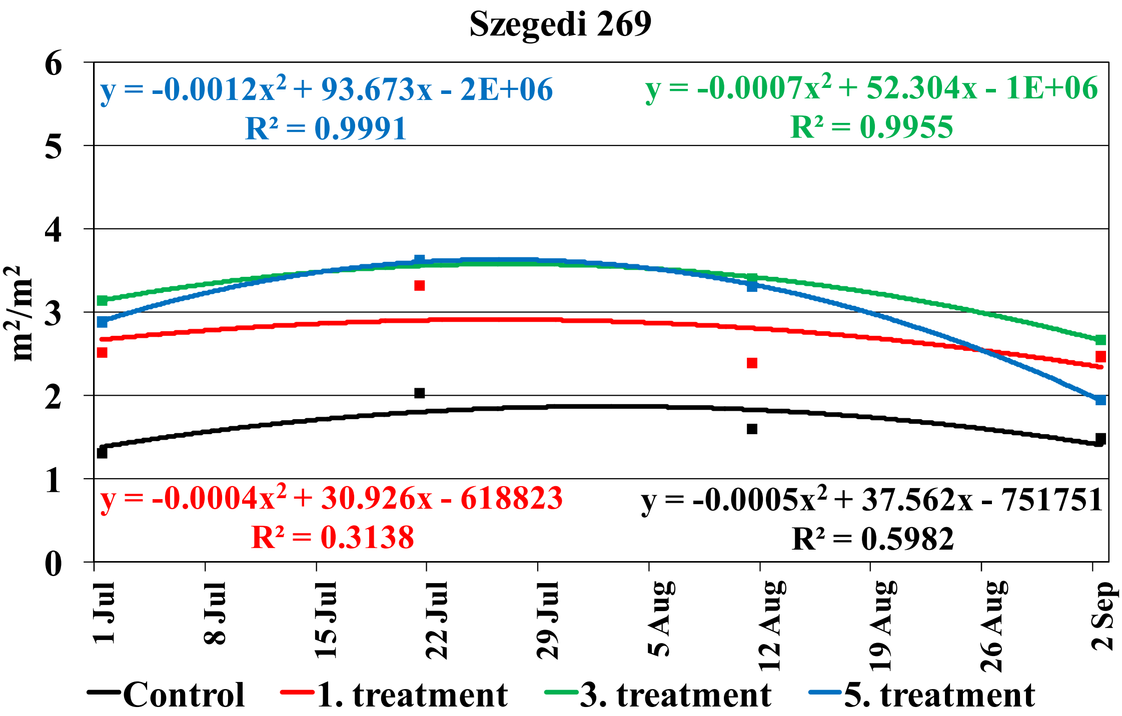


Figure 15: Effect of fertilization on the leaf area index (Szegedi 269, 2005)

At earlier sowing, the leaf area of the hybrids is larger in the first period of the growing season, which determinates basically the further development of the plant (*Figure 16*). The developed foliage encourages pulling through the drought period easier with less damage, thereby the potential yield, that is, the yield security increases.

In all the three years of the experiment the increasing plant density affected the leaf area index positively (*Figure 17*). The rate of rising was in each year different.

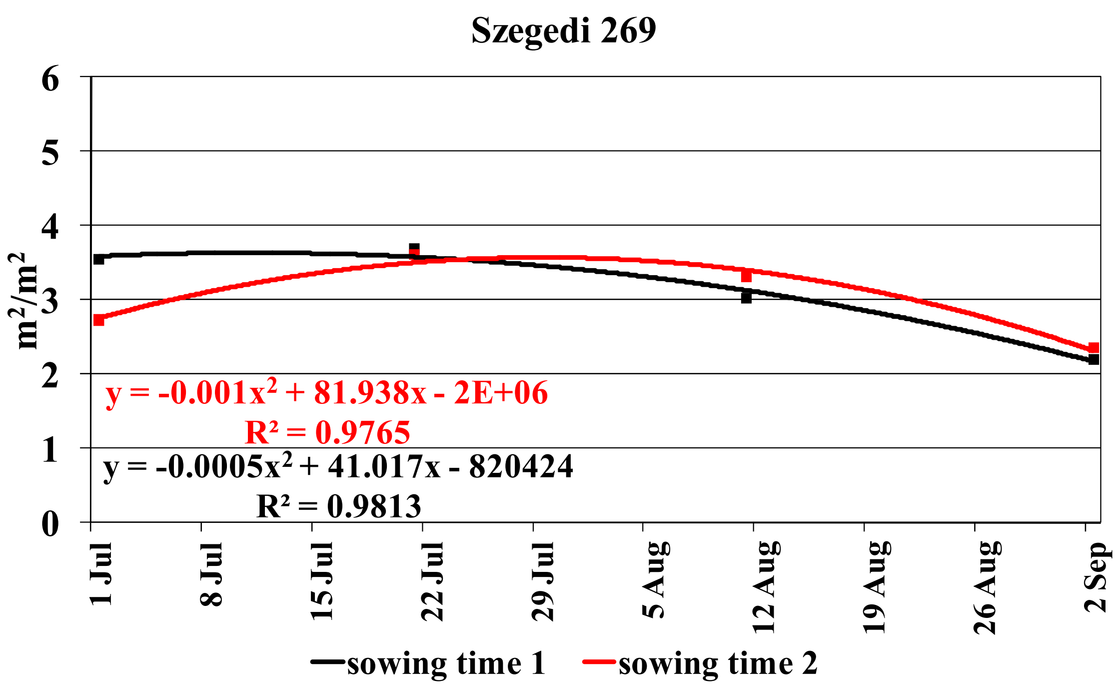


Figure 16: Effect of sowing time on the leaf area index, (Szegedi 269, 2005)

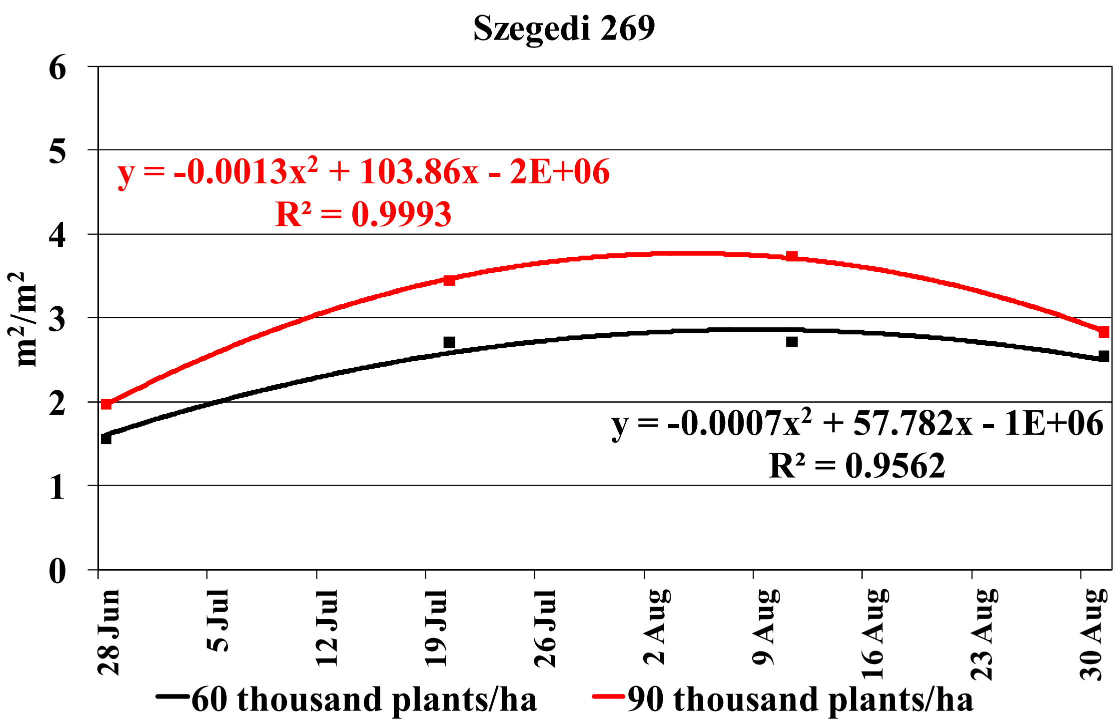


Figure 17: Effect of plant density on the leaf area index, (Szegedi 269, 2005)

4. Relationship between the tested agro-technical factors and the quality of maize

4.1. Effect of fertilization on the quality of maize hybrids, 2005-2007

We analysed the quality at Szegedi 269, NK Cisko and PR34B97 hybrids. In 2005, as a result of the improving nutrient supply the protein and oil content of the tested hybrids increased on the contrary the starch content decreased (*Figure 18*).

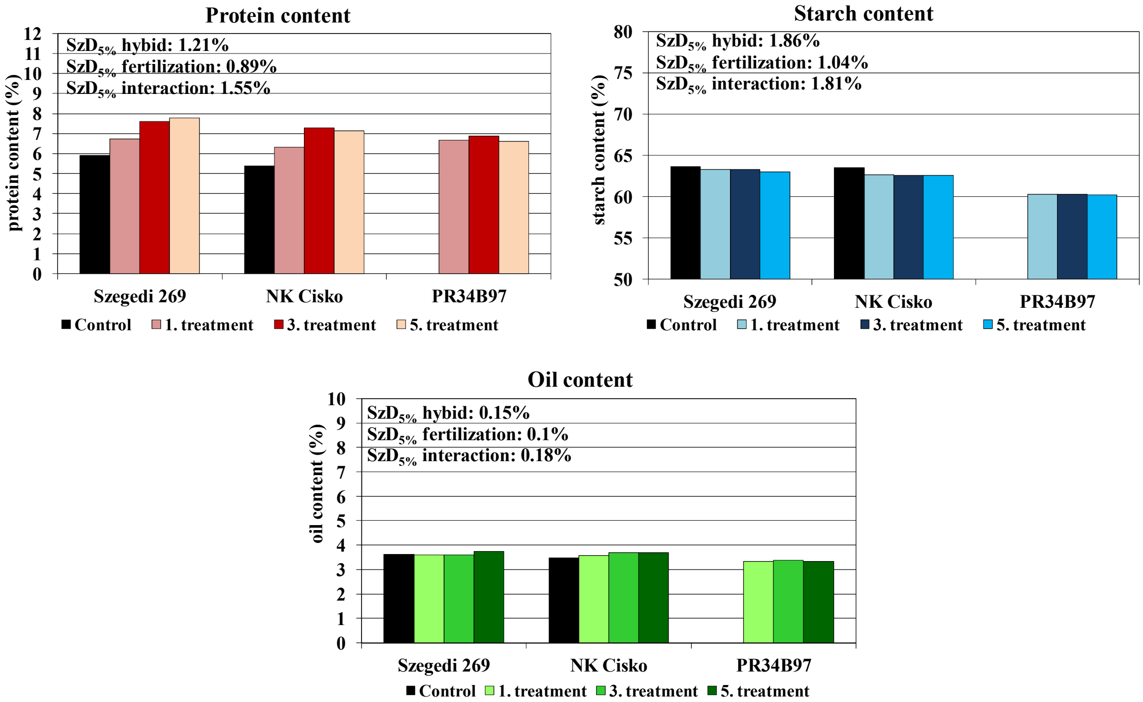


Figure 18: Effect of fertilization on the quality of maize, 2005

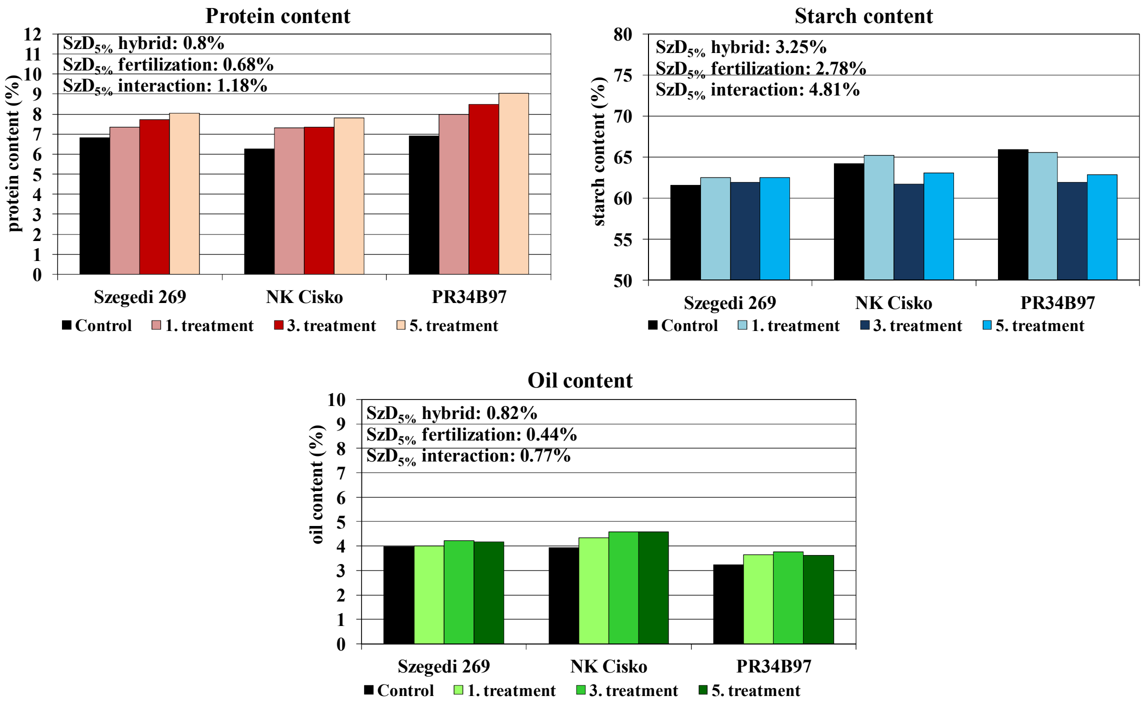


Figure 19: Effect of fertilization on the quality of maize, 2006

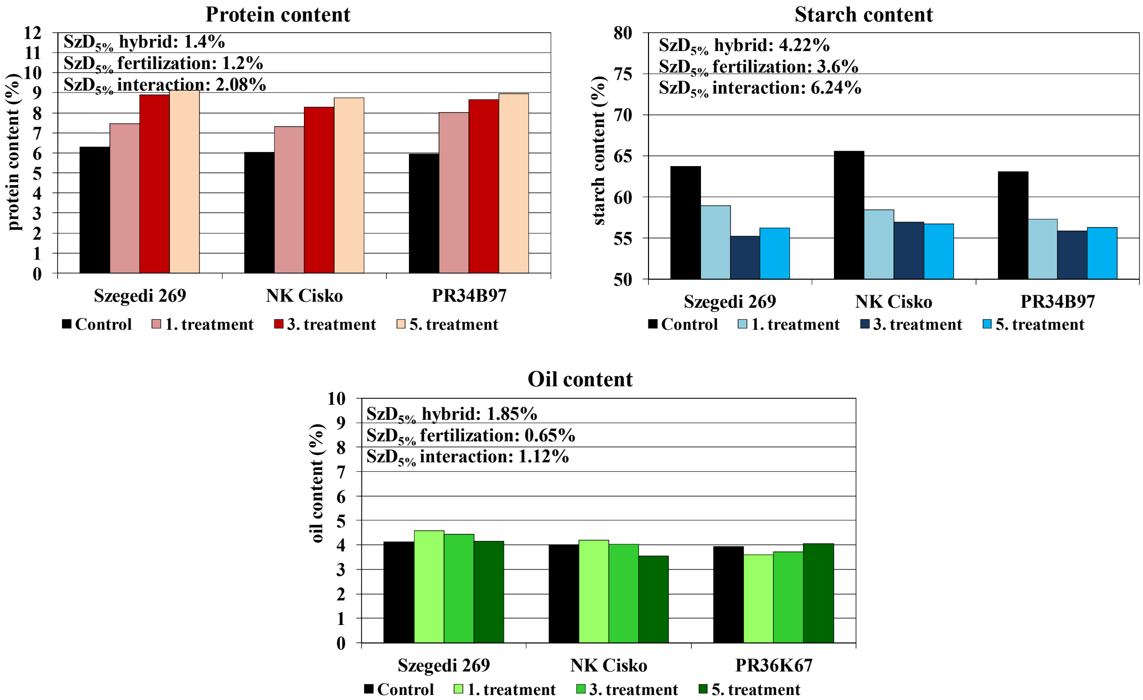


Figure 20: Effect of fertilization on the quality of maize, 2007

In 2006, owing to the little dose of fertilizer the protein content increased greatly, in the cases of NK Cisko and PR34B97 significant compared to control (*Figure 19*). Applying higher doses, the starch content of NK Cisko and PR34B97 hybrids decreased significantly and it was the lowest at the optimal fertilizer dose. Oil content – like in 2005 – was higher through nutrient supply.

As a result of the improving nutrient supply the protein content of the hybrids tested increased on the expense of the starch content (*Figure 20*), the oil content was lower at more intensive fertilization, on the contrary to the tendencies of the previous years.

Table 10: Statistical analysis

r	**protein**	**starch**	**oil**
seed moisture content at harvest	**-0.588****	**0.591****	**-**
protein	**-**	**0.996****	**-0.420****
starch	**-**	**-**	**0.395****
precipitation July	**-**	**-**	**-0.923****
precipitation August	**-0.742****	**0.764****	**-**
precipitation September	**-**	**-**	**-0.901****
temperature July	**-**	**-**	**0.532****
temperature August	**0.983****	**-0.980****	**-**
temperature September	**-**	**-**	**0.518****

4.2. Effect of sowing time on the quality of maize hybrids, 2005-2007

In 2005, later sowing resulted in higher protein content in the cases of Szegedi 269 and PR34B97 hybrids, and in the case of NK Cisko it was lower (*Figure 21)*, furthermore the starch and oil content of the seed was less at second sowing time.

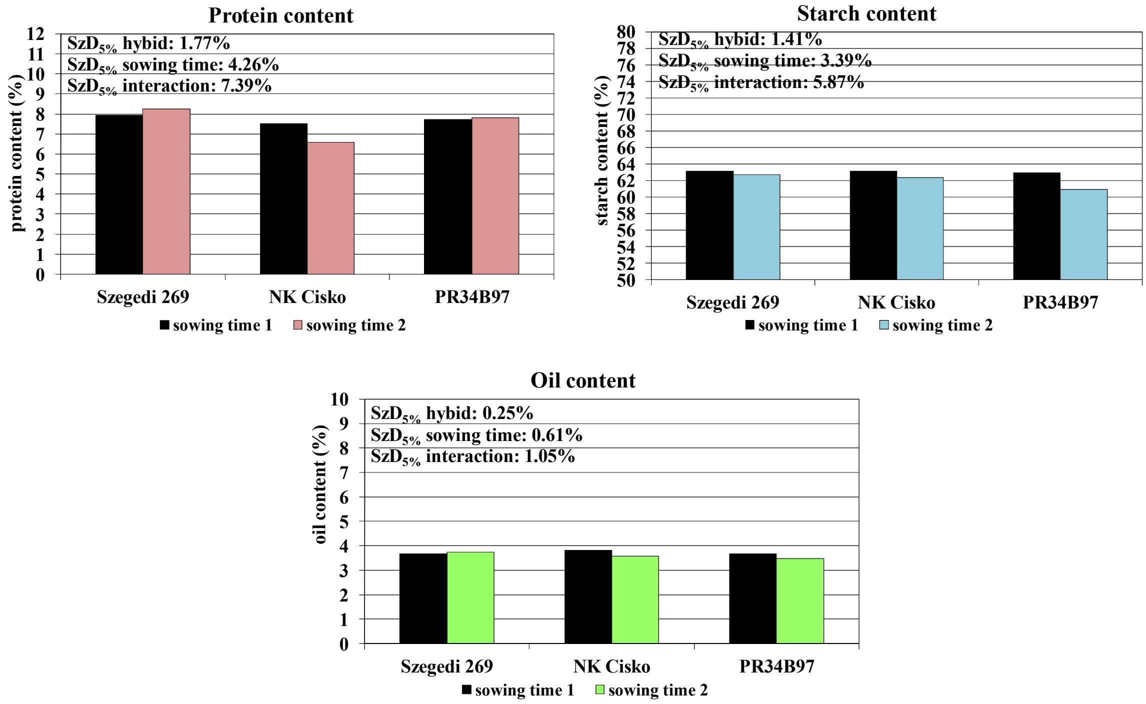


Figure 21: Effect of sowing time on the quality of maize, 2005

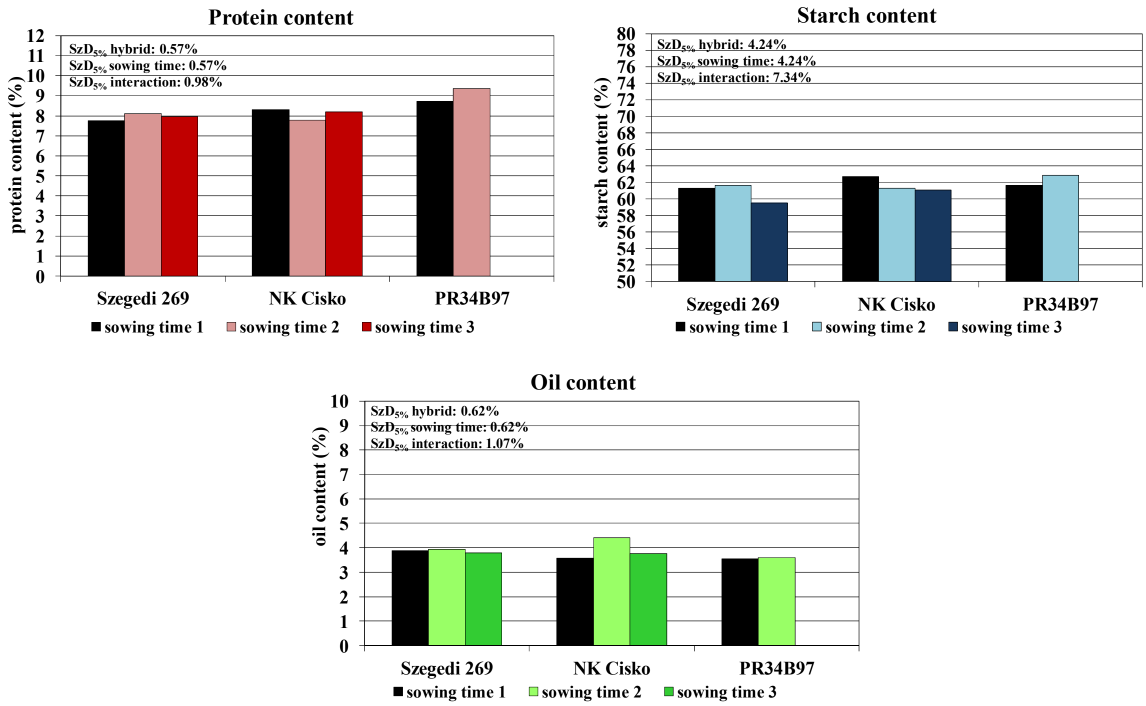


Figure 22: Effect of sowing time on the quality of maize, 2006

In 2006, the protein content of the hybrids fluctuated depending on the sowing date (*Figure 22*). While its concentration was the highest at the second sowing date in the case of Szegedi 269, by NK Cisko the early and late sowing had positive effect. The protein content of PR34B97 increased significantly at the second sowing time. Starch content of Szegedi and NK Cisko decreased greatly at the third sowing time. The oil content of NK Cisko changed considerably.

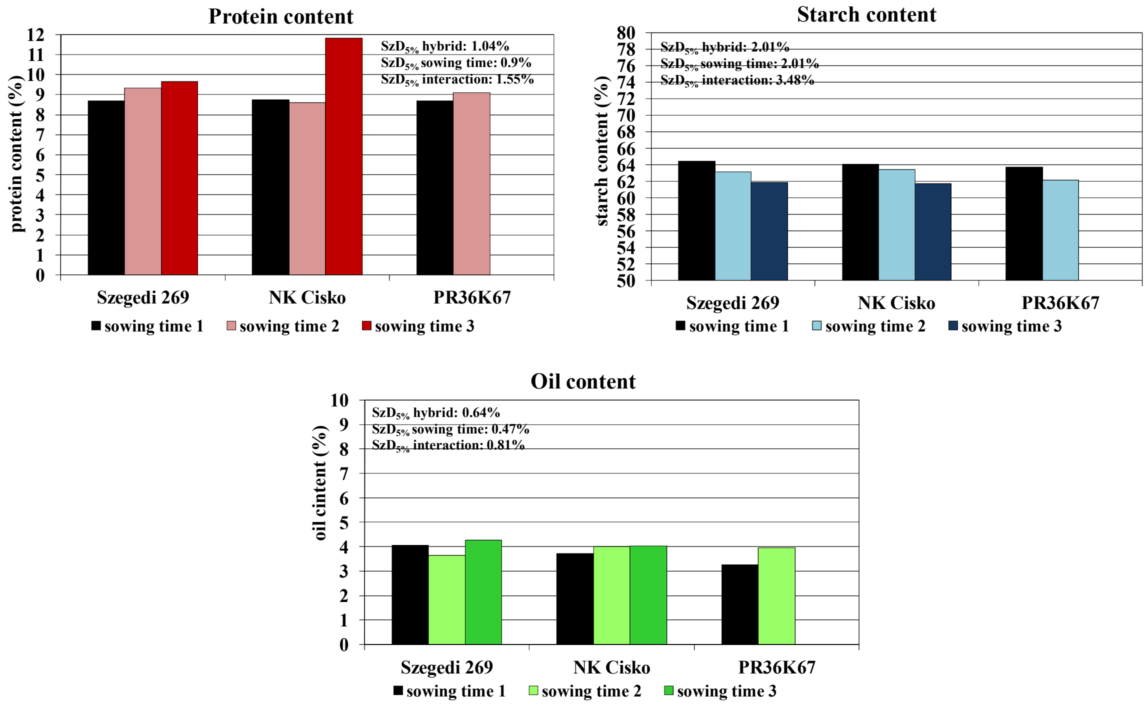


Figure 23: Effect of sowing time on the quality of maize, 2007

In 2007, owing to the delaying sowing the protein and oil content of the hybrids was higher and the starch content on the contrary was lower (*Figure 23*).

Table 11: Statistical analysis

r	protein	starch	oil
hybrid	-	-	-0.279**
sowing time	0.339**	-0.379**	0.289*
seed moisture content at harvest	-	-0.266**	-
precipitation July	-	0.345**	-
precipitation August	-0.618**	-	-0.264*
precipitation September	-	0.432**	-
temperature July	0.504**	-	-
temperature August	0.552**	-	-
temperature September	-0.564**	-0.386**	-

NOVEL SCIENIFIC RESULTS

1. In wet years (2005) the yields of DK 440 and Mv Maraton hybrids, in average years (2006) NK Cisko and PR34B97 and in dry years (2007) PR37D25 and PR6K67 were outstanding without fertilizers compared to the other hybrids. By applying the smallest fertilizer dose of 40 kg N+PK a production increase of 41-191% could be reached depending on the weather conditions. The fertilizer reaction of PR37D25 and Szegedi 269 hybrids are excellent
2. The agro-ecological optimum of fertilizer is significantly influenced also by the given year. In wet years no significant differences could be seen regarding the fertilizer requirement of the hybrids among experimental conditions; cca. 110-150 kg/ha N+PK fertilizer doses were sufficient to obtain maximal results. In average years the genetic variability was more dominant in the fertilizer optimum. The larger agro-ecological fertilizer optimum (NK Cisko: 168-228 kg/ha N+PK) means that among optimal environmental conditions the hybrid can utilize larger than usual quantities of fertilizer. This is a very significant characteristic regarding the environmental load and the proper nutrition utilization. In dry years the optimal fertilizer interval narrowed and the hybrids required less nutrition.
3. As a result of the better nutrition supply the protein content of the hybrids increases and the starch content decreases. The infiltration of protein is limited by the wet weather in June and August. The concentration of oil is facilitated by the warm weather in June and by the dry weather of July and September. High seed moisture content is coupled with high starch contents.
4. In wet years the maize hybrids reacted to the density increase by continuous production increase. In average years the reaction difference among the hybrids was more significant. The optimum interval of Szegedi 269, PR34B97 and NK Cisko hybrids was wide; Mv Maraton hybrid is characterized by narrow and very low plant density values. In dry years the optimal plant density is 60-75 thousand plant/ha. Szegedi 269 tolerates well the varying plant density and NK Cisko and a PR36K67 tolerates less the lacking water supply.
5. The sowing later than optimal decreases the starch content significantly, increases the protein and oil fraction. The oil content of the hybrids of long growing period is characteristically lower. The wet April-June is unfavourable for the starch content of the seeds, but the wet weather in July and September has a positive effect. The

concentration of protein and oil is facilitated by the warm and sunny weather in summer.

6. Besides the genetic characteristics of the hybrids the development of the LAI index is determined also by the ecological and agrotechnical factor. The increasing fertilizer doses and the density increase the maximal leaf area of the maize hybrids significantly. The LAI index of the hybrids sown earlier was considerably higher at the beginning of the growing period than in the case of the plants sown later. The relationship between leaf area index and yield is expressing in favourable years better.

RESULTS FOR PRACTICAL UTILIZATION

1. Besides the production area and the hybrid-specific technologies the results obtained make the efficiency increase possible
2. The water loss of the hybrids during the growing period is more favourable in the case of optimal NPK treatment, at the lowest value of the plant density interval and at earlier sowing time.
3. The application of a plant density, fertilizer dose and sowing time unlike the optimal in addition to decreasing the yield security it increases also the seed moisture content at harvest time by hampering the biological and physical water loss of the seeds.
4. The determination of the most important agronomic characteristics of the hybrids tested and the adaptation of the results facilitate the application of the hybrid-specific production technologies, the efficiency increase and in addition the sustainable development in maize production.
5. Production security of maize production can only be reached by optimizing the relationship among the ecological, biological factors and the agro techniques applied.
6. The production area and the application of hybrid-specific agro techniques are the prerequisites of the efficiency and environment protection.

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