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Theses of Doctoral (Ph.D.) Dissertation

THE IMPORTANCE OF NUTRIENT SUPPLY IN THE HYBRID SPECIFIC CORN PRODUCTION

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1. Introduction

The ecological conditions of Hungary determine the way the soil is used, consequently 60% off the arable land is used to grow cereals. Maize together with silagemaize is the plant which is cultivated on the largest area since 1946, and probably it will play a vital role in the structure of crop production also in the future.

The level of crop production in Hungary has risen rapidly since the beginning of the seventies, moreover the results by the end of the eighties were among the international bests. During this period the national average yield of maize exceeded the 6 tonnes/hectare level in the consequent years. By achieving these yields Hungary was among the bests of the countries producing maize on more than 1 million hectares. Many factors contributed to the development of the technology of maize production and to the achievement of outstanding yields such as the production of new breeds and hybrids, the development of agrotechnology, the improvement of technical, tchnological level and fertilisation in large amounts. The latter one considerably contributed to the increase of yields; this is proved by the studies of several researchers engaged in this issue.

After 1990 the level of inputs decreased to a large extent. Within the use of chemicals the reduction in the dose of nutrients have particularly been adverse to the production of maize and to the whole plant production sector. This have been coupled with frequent draughty years that caused the alteration in yields to increase from 10-20% to 30-50%, moreover average yields decreased significantly.

The success of crop production is determined by the complex effects of ecological, biological and agrotechnical factors. The better farmers can adjust to the ecological conditions the higher and more stable the level of production. One of its ways is to produce hybrids with excellent genetic makeup that are available at in the national markets. The other way is to apply adequately certain agrotechnical factors such as nutrient supply. To determine the optimal nutrient supply is crucial as it has a considerable effect not only on the volume and quality of yields and the environment but also on the effectiveness of production.

In my research, I measured the effects of the factors of plant production, with emphasis on the nutrient supply in the soil, on the traits of 10 corn hybrids with different genotype and on the physiology process important for yield formation, which are the following:

- Productivity of corn hybrids
- Natural nutrient exploration and utilisation capacity,
- Water-release capacity of hybrids, grain loss at harvest
- protein, starch and oil content of kernels
- content of macro-, meso-, and microelements
- The extent of different toxins and fungal infection
- Leaf area index of hybrids and its change during the vegetative period
- The activity of photosynthesis

I carried out my research from the conviction that the results obtained should be utilised on the geographical areas with similar ecological character, furthermore, newer information shall be obtained that help in the elaboration and specification of technologies for each variety, respectively.

2. Materials and Methods

2.1. Soil properties of the experimental field

The experiment was set in the demonstration garden of the Department of Crop Production and Applied Ecology in the Agricultural Centre, at the University in Debrecen.

The soil of the experiment is calcerous chernozem soil. Humus accumulation and easy tillage are typical for this soil. In the topsoil leaching is typical, lime can not be found there. The amount of carbonates is increasing gradually downwards, and forms a precipitate in the form of colloid or microcystal in one layer. The soil was susceptible to cracking in dry periods originating from lime deficiency. The nutrient supply of the soil is satisfactory, its nutrient dynamism is good. Humus is 50 to 70 cm thick in “A” horizon. Organic matter content is 2.57 %. Soil plasticity value (K_A) = 45, pH=7.0, N-content = 0.12 %, Al-soluble P_2O_5 = 100 mg/kg, K_2O-content = 165 mg/kg (table 1)

Table 1 Main properties of the experimental field are shown

pH (H_2O)	$CaCO_3$	P_2O_5 (mg/kg)	K_2O (mg/kg)	Humus (%)	Soil plasticity value (K_A)
7.0	In traces	100	165	2.57	45

2.2. Weather in the experimental years

During the 3 years period of the experiment (1999-2001) favourable and less favourable periods we also had.

In 1999, the distribution of precipitation was really favourable within the vegetative period, as a consequence, corn developed well, and the development of the cob and the grain was also adequate. In comparison with the average of the last 30 years, the average temperature was higher, which was especially advantageous for the development of a good average yield besides the favourable amount of rainfall.

In 2000 and 2001 the amount of precipitation in the vegetation period of corn was lower than the average of 30 by 64.4 and 23.9 mm respectively. The average temperature showed a positive deviation compared to the average of several year. The positive deviation of average temperature together with deficient precipitation had a negative effect on the development of corn, which resulted in lower yields in the 2 past years. Therefore, the year 2000 was unfavourable and the year 2001 was a medium concerning corn yields.

2.3. Main characteristics of corn hybrids tested in the experiment

10 hybrids were set into the experiment in 1999-2001. The aim of the experiment was to involve hybrids of domestic and foreign breeding and with different groups of maturing time (really early, early, medium, late maturity) (table 2).

Table 2 The hybrids of the experiment

Hybrid	Vegetative period (FAO-number)
1. Monessa SC (Pi. 3905)	270
2. DK 366 SC	310
3. Norma SC	380
4. Evelina SC (Pi. 3752)	380
5. Debreceni SC 351	380
6. DK 471 SC	410
7. Veronika (Sze SC 427)	460
8. Colomba SC	480
9. Filia SC (Pi. 3515)	500
10. Mv TC 514	550

2.4. The main features of the agrotechnical applied

Five fertilisation steps were applied in I-III replication besides the control in the three experimental years (1999, 2000, 2001), where the smallest rate was 40 kg N; 25 kg P_2O_5; 30 kg K_2O of active ingredients. The largest rate was five times more than the smallest one: 200 kg N; 125 kg P_2O_5; 150 kg K_2O, which is equal to 475 kg mixed active ingredients. Nitrogen was applied in autumn and spring in 50-50 %; the total amount of phosphorus and potassium was applied in autumn.

Fall tillage involved deep ploughing at 30-35 cm depth in all three of the experimental years.

Secondary tillage in spring and the preparation of the seedbed took place with heavy harrow. In 2001, seed bed was prepared with twice harrowing and with spring tine harrow.

In 1999, chemical weed control was carried out with Primextra 500 FW at 6 l/ha rate. In 2000, we used the combination of Lontrell (0.5 l/ha) and Starane (1.5 l/ha) and in 2001 Primextra 6 l/ha + Motivell 1l/ha. In each year we hoed the experimental fields, too.

2.5. Supplementary tests and their method

2.5.1. Photosynthesis measuring device and the description of its operation

The portable photosynthesis measuring device of LI 6400 is the product of LI-COR Company. Its operation is based on infra-red laser light absorption. Its task is to measure CO_2, that operates under the following principle:

At the beginning of the measure, the leaf of the corn (or of any other plant) is fixed in the measuring reference chamber. The CO_2 content of the air leaving the chamber is compared to that of the incoming air and calculates the CO_2 absorbed. Intensity of photosynthesis, the amount of intercellular CO_2 (CO_2 between cells), stoma openness and permeability are then calculated by different algorithms from the amount of CO_2 absorbed.

Before measuring, the device must be calibrated. Measuring is carried out under controlled light intensity. Apart from foton-intensity, temperature (temperature of the leave and the surrounding air) and atmospheric pressure are also recorded.

We measured the first leaf above the corncob at every time (Dates of measurements in 1999: 1st July, 22nd July, 16th August, 15st September, in 2000: 28th June, 25th July, 21st August, in 2001: 26th June, 19th July, 10th August, 28th August).

The photosynthesis-meter registered the amount of CO_2 assimilated by the leaf (mmol/m^2).

We examined the Monessa SC, Evelina SC and the Mv TC 514 hybrids. The measurements were conducted in control (without fertilisation), 1 (N_{40}+PK kg/ha), 3 (N_{120}+PK kg/ha) and 5 (N_{200}+PK kg/ha) fertilisation treatments.

2.5.2. Method and time for measuring leaf area (LA)

In the vegetative period of corn, in each experimental year (1999, 2000, 2001) we measured the leaf area of Monessa SC, Evelina SC, Veronika SC and Mv TC 514 hybrids, respectively. We chose hybrids of different maturing times. The Monessa SC is a FAO 270, the Evelina SC is FAO 380, the Veronika SC is FAO 460 and the Mv TC 514 is FAO 550.

Measuring took place in the control (without fertilisation), and the II. and the III. replication at the fertilisation levels of 1 (N_{40}+PK kg/ha), 3 (N_{120}+PK kg/ha) and 5 (N_{200}+PK kg/ha) during which the length and width of the leaf of the living plant was measured by hand, from which leaf area (LA) for each leave and leaf area index (LAI) was calculated by applying Montgomery-formula:

LA (m^2/piece)=leaf length (m) x leaf width (m) x 0.75

LAI (m^2/m^2)=LA(m^2/piece) x PPD (piece/m^2)

PPD=plant population density (piece/m^2)

Measured plants were marked, therefore the same plants were measured every time in each lot.

2.5.3. Measuring the water release dynamics of corn hybrids and moisture content of kernels at harvest

Samples needed for measuring were picked in every seventh day and were put into the airing cupboard and were dried until they reached their permanent weight and then moisture content was measured. Samples were picked from several different lots, the control lot, and from the repetitions of second and third at fertilisation levels of 1 (N_{40}+PK kg/ha), 3 (N_{120}+PK kg/ha) and 5 (N_{200}+PK kg/ha). The Monessa SC, the Evelina SC, the Veronika SC and the Mv TC 514 were measured for moisture content.

Sampling took place 5 times between 6 September and 7 October in 1999, 4 times between 4 September and 21 September in 2000 and 5 times between 28 August and 25 September in 2001.

On the basis of the results, we evaluated the effect of nutrient supply on the pace of water release and moisture content of kernels at harvest.

2.5.4. Analysis of the element content of kernels

N, P, K, Ca, Mg and Zn contents of seed samples of Monessa SC, Evelina SC, Veronika SC and Mv TC 514 hybrids were analysed in control (without fertilisation), 1 (N_{40}+PK kg/ha), 3 (N_{120}+PK kg/ha) and 5 (N_{200}+PK kg/ha) fertilisation treatments.

The measurements were carried out by Dr. Zoltán Győri and his colleagues at the Department of Food Science and and Quality Assurance.

Sample preparing method of wet-destruction by HNO_3-H_2O_2 was applied to determine the macro-, meso-, and micro element content of the samples of fodder-basic material and the fodder. Depending on the type of the appropriately prepared (dried, ground) sample, the quantity of the weighed material is 1.2 or 3 g. During pre-destruction, 10 cm³ of HNO_3 was applied on 60 °C for 30 minutes. Before the main destruction 3 cm³ 30 % H_2O_2 was added, then the destructed material was kept on 120 °C for 90 minutes.

The N content was determined by *Wagner-Parnas's* Microkjeldahl method. As regards mineral substances the plant material was prepared by cremation, then K was determined by flame-photometry, Ca, Mg, Zn, by atom-absorption method from the stock-solution.

2.5.5. Testing method for protein, starch and oil content of kernels

We examined the Monessa SC, Evelina SC and the Mv TC 514 hybrids. The measurements were conducted in control (without fertilisation), 1 (N_{40}+PK kg/ha) and 5 (N_{200}+PK kg/ha) fertilisation treatments. All of the three measurements were also carried out at the Department of Food Science and and Quality Assurance by Dr. Zoltán Győri and his colleagues.

2.5.5.1. Protein content analysis

According to the principle of the method the fodder was destructed with concentrated sulphuric acid, its N-content was converted into ammonium-salt, then the ammonia released was titrated into sulphuric acid or boric acid by distillation. Distillation of protein was carried out with *Kjeltec* half-automatic device. The protein content was an average calculated from two parallel analyses.

2.5.5.2. Starch content analysis

Fodder sample was boiled with diluted hydrochloric acid for a given period of time. After the precipitation of proteins, optical rotational capacity of the filtrated solution was measured by polarimeter. The rotation value obtained was corrected by the value of the optical rotational value of components soluble in 40 (V/V)% ethanol and treated with dilute hydrochloric acid.

2.5.5.3.Oil content analysis

The sample was extracted by dietil-ether then the raw oil was separated from the solvent by distillation, later dried and its weight was measured. The raw oil content is an average calculated from two parallel measuring. The analysis was carried out by *Soxtec* half-automatic device.

2.5.6. Determining the fungal infection of kernels

The analysis took place at the Authority of Plant Health and Soil Protection, Hajdú-Bihar County. After preliminary surface disinfection and two distilled water used rinsing, we incubated 200 kernels per sample in sterile moisture chamber. Later, the visual (occasionally microscope used) measuring of the fungal.

The method of sampling and the examined hybrids are the same as described in 2.5.5.

2.5.7. Measuring the toxin content of corn hybrids

We endeavoured to determine the amount of T-2, DON, DAS, F-2 among the Fusarium toxins. Measuring was carried out at the Department of Food Science and and Quality Assurance by Dr. Zoltán Győri and his collegaues.

These toxins have economic importance and often occur in cereals. Sample preparation: 20 g of finely ground sample was extracted with methanol: water (1:1), the extract was purified with SPE. A *Merck Hitachi* liquid chromatograph equipped with *AS-4000* autoinjector system and *L-4500* diode array detector was employed. An RP-18 5μm column (125x4 mm) and gradient elution with acetonitrile and water was used. To identify and quantitaively determine different toxins mixed standard solutions were used. The measurable limit of mycotoxins: T-2: 0,062 µg/kg, DON: 0,080 µg/kg, DAS 0,058 µg/kg, F-2: 0,003 µg/kg.

The method of sampling and the examined hybrids are the same as described in 2.5.5.

2.5.8. Method of result evaluation

I processed the obtained data by single- and double factor variant analysis (SVÁB 1981 and SPSS for windows statistic program) and SPSS 9.0 for Windows. The figures was made by Microsoft Excel 97, the evaluation of results in writing made by Microsoft Word 97.

3. Results

3.1 The effect of NPK fertilisation on the yield of corn hybrids

1999 was a favourable year for corn production. The hybrids usually reached their highest yields, 12.17-15.26 t/ha, at N_{200}+PK kg/ha active nutrient. The Colomba SC (15.26 t/ha) and Filia SC (14.77 t/ha) were the hybrids with highest yields (figure 1).

The year 2000 was unfavourable for corn production. The maximum yield of the hybrids were 1.74-3.14 t/ha less than the results of 1999. The Filia SC (13.03 t/ha) and Colomba SC (12.42 t/ha) were the hybrids with highest yields (figure 1).

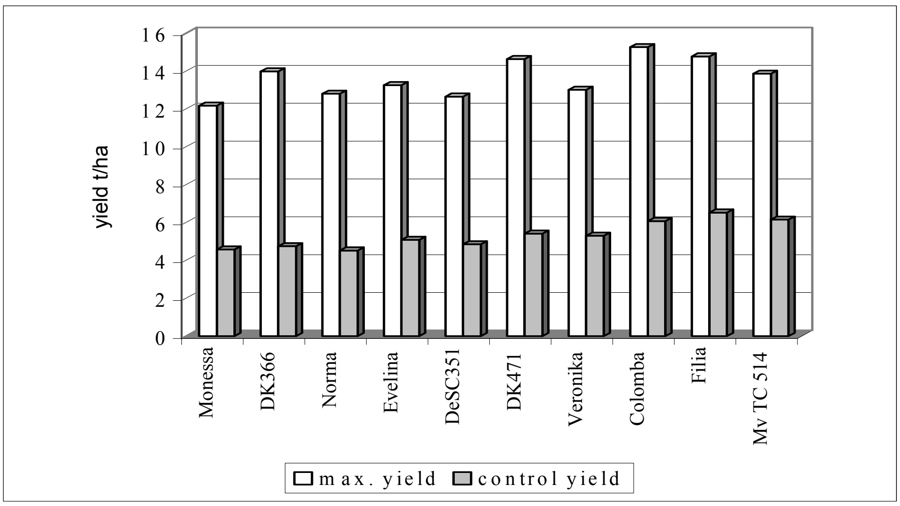
2001 was an average year for corn production. The hybrids yielded the maximum at 11.2-13.23 t/ha at an increased rate of N_{160}+PK kg/ha and N_{200}+PK kg/ha.

The Colomba SC (13.23 t/ha) and Filia SC (13.18 t/ha) gave the biggest yield (figure 1). In all years, the hybrids Filia SC, Mv TC 514 and Colomba SC had the best natural nutrient exploration and utilisation capacity (figure 1).

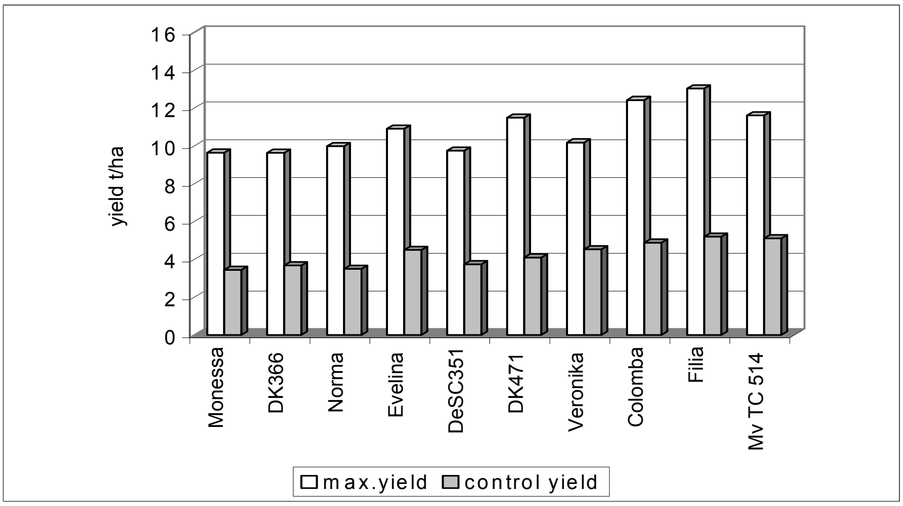
The year effect determines also the efficiency of NPK fertilisation to a great extent besides having impact on the yield of hybrids. In the three examination years economical and reliable yield increase was achieved by N_{40-120}+PK kg/ha active nutrient dose depending on the hybrid and the year.

Figure 1 Maximum and control yields of corn hybrids, Debrecen (1999-2001)

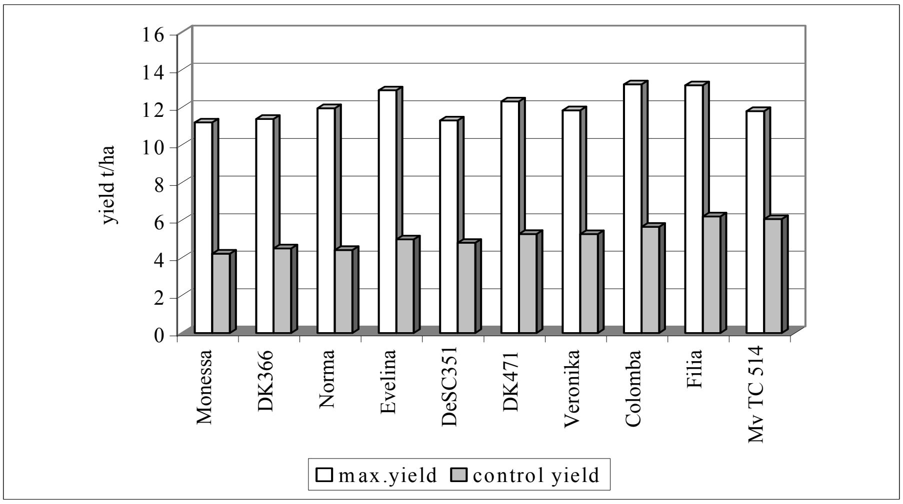
1999



2000



2001



3.2. Measuring the water release dynamics of corn hybrids and moisture content of kernels at harvest

Observing the dynamics of water-release capacity and the grain loss at harvest of hybrids, it can be found that besides the vegetative period and the genotype of the hybrid, the growing condition of the given year (mainly the precipitation) and the nutrient supply are with great effect.

If the growing conditions are favourable, the corn will wilt later, therefore, it longer lets out the water through the leaves, so the moisture content of harvested kernels will also be lower. As a consequence of the above, an unfavourable drought year will result in earlier maturing, the moisture content is at an early lower rate. However, the rate of water-releasing decreases because of the fast wilting, therefore, the moisture content of the kernels are higher at harvest.

The effect of nutrient supply on the moisture content of kernels at harvest is complex. Increasing the supply of nutrients to a certain level (up to the optimal rate), the moisture content measured at harvest can be decreased. The over-supply of nutrients, however, results in increased harvest moisture content.

In my research I experienced that the 1 and the 3 treatment of fertilisers (N_{40}+PK kg/ha, N_{120}+PK kg/ha) decreased the moisture content of kernels at harvest in several cases compared to the control and the highest rate of application (N_{200}+PK kg/ha) (table 3).

The optimal rate concerning the amount of yield and the moisture content at harvest, is N_{120}+PK kg/ha.

The vegetative period of hybrids also has an effect on the moisture content at harvest. The moisture content of kernels of early maturing hybrids at harvest is usually lower than middle- or late maturing hybrids. These days, one of the aims of hybrid breeding is to increase the length of maturing time on green stem., therefore, make it possible to reach a favourable moisture content of FAO 400-500 hybrids at harvest besides good yields, which results in decreased drying cost.

Table 3 The effect of nutrient supply on the moisture content of kernels at harvest 1999-2001

Treatment	Monessa SC			Evelina SC			Veronika SC			Mv TC 514		
	1999	2000	2001	1999	2000	2001	1999	2000	2001	1999	2000	2001
control	16,0	16,0	20,0	25,0	22,0	25,0	23,0	21,0	23,0	29,0	31,0	29,0
1 treatment	15,0	14,0	18,0	24,0	21,0	24,0	22,0	20,0	22,0	28,0	29,0	28,0
3 treatment	15,0	14,0	17,0	23,0	21,0	24,0	21,0	19,0	22,0	28,0	28,0	28,0
5 treatment	16,0	16,0	19,0	25,0	24,0	25,0	22,0	20,0	24,0	29,0	29,0	29,0
$LSD_{5\%}$	**1,0**	**1,1**	**1,29**	**1,0**	**1,73**	**1,0**	**1,15**	**1,73**	**2,0**	**1,0**	**1,15**	**1,29**

3.3. The effect of NPK fertilisation on the protein, oil and starch content of hybrids with different genetic properties

According to the results of two years, the increase of fertilisers applied resulted in the increase of protein of all the hybrids. The increase, compared to the control application, is statistically justified with the Evelina SC and Veronika SC hybrids. All the hybrids reached their maximum protein rate at the maximum rate – N_{200}+PK kg/ha – of fertilisers.

The oil content of our hybrids was slightly increased by the fertiliser at N_{40}+PK kg/ha compared to the control application. The spread of the highest rate (N_{200}+PK kg/ha) increased only the oil content of the Evelina SC, while a slight decrease we experienced at the rest of the hybrids. The oil content of the Evelina SC was significantly higher at N_{200}+PK kg/ha than at the control or N_{40}+PK, however, the oil content of the Mv TC 514 was the smallest at N_{200}+PK kg/ha, which statement is supported by statistical data.

The more fertiliser we spread, the smaller starch content the kernels had. The starch content of the hybrids at control application was 64.19-67.1% while the same parameter was 60.39-63.84 % at the highest rate. However, the decrease could be statistically justified only for the Evelina SC. Its starch content was significantly lower in the N_{200}+PK kg/ha treatment, then without fertilisation.

3.4. The effect of fertilisation on the macro, meso and micro element content of corn hybrids

The application of NPK fertilisers significantly influenced the macro, meso and micro element content of the hybrids. The N content was the lowest at control application, while all the other fertiliser rates increased significantly the N content on average, which is closely connected to the protein content. However, the phosphorus and potassium content was always the highest at control and the smallest at N_{200}+PK kg/ha. Increasing the rate of phosphorus fertiliser we can obtain a slight, not significant decrease, however, the potassium content considerably decreased at higher rate of fertilisers. Compared to the control, the rate of N_{120}+PK kg/ha and N_{200}+PK kg/ha decreased the potassium content significantly. The magnesium content of the hybrids reached its maximum at the control rate. Increasing the NPK rate the Mg content decreased and we measured significantly lower Mg value at N_{120}+PK kg/ha and N_{200}+PK kg/ha. The Ca content was at N_{120}+PK kg/ha the highest and reached the lowest value at N_{200}+PK kg/ha, which was significantly lower than at N_{120}+PK kg/ha. Zinc is the most important microelement for corn. Zinc deficiency causes problems of fertility, therefore the plant yields less. The zinc content of the hybrids reached their maximum at control. The more fertiliser we spread, the less zinc content of corn we obtained. The smallest rate we measured at N_{200}+PK kg/ha. The explanation: the highest yields take away the most zinc from the soil; zinc supplement is with primary importance at poor supply.

3.5 The effect of fertilisation of hybrids with different genetical background on the extent of fungus-infection and toxin content

In 1999 out of 10 hybrids in the research, the Monessa SC, the Evelina SC, the Veronika SC and the Mv TC 514 hybrids were examined for Penicillium spp., Aspergillus spp., Fusarium spp. and Alternaria spp. Examining the rate of fungal infection, the Penicillium spp. and the Fusarium spp. are fungal with the greatest occurrence. The rate of infection of Aspergillus spp. is very low and the Alternaria spp. was hardly present. NPK fertilisation had a slight effect on the fungal infection of the hybrids, while the traits of the grown hybrid effect infection to a greater extent as proved by statistical calculations. Among the different fertilisation treatments, there were significant differences in the infection of the hybrids. Infection by Fusarium spp. was significantly higher for Mv TC 514 and Evelina SC grown without fertilisation compared to that of Monessa SC and Veronika SC. Infection by Aspergillus spp. was higher for Evelina SC at N_{200}+PK active nutrient dose than that of the other three hybrids examined. Also, the infection by Fusarium spp. was higher for Mv TC 514 compared to that of Veronika SC.

The rate of the examined toxins (F-2, T-2, DON, DAS) was really low, in some cases they were not present in the sample. The DON toxin was present at the lowest rate, while the T-2 had the greatest occurrence in the samples. Fertilisation did not have significant effect on toxin content, even hybrids with different genetic background did not show significant alteration. The Monessa SC was not infected by either of the toxins.

3.6. The effect of fertilisation on the LAI-value of corn hybrids

During the vegetative period of the corn we measured four times in all three years (1999, 2000, 2001) the leaf area of the Monessa SC, the Evelina SC, the Veronika SCand the Mv TC 514, respectively.

In 1999 the late maturing Mv TC 514 hybrid had the highest LAI-value and the highest yield, too. Owing to the favourable weather conditions, the LAI-value of hybrids increased up to the highest rate – N_{200}+PK kg/ha – of fertiliser. We experienced the maximum LAI-value of hybrids on 26^{th} July (3,86-4,96 m^2/m^2).

The year 2000 was unfavourable for corn production, therefore, the LAI-value of the hybrids was lower than the previous year. We experienced significant increase in the LAI-value at rate N_{120}+PK kg/ha.

The LAI-values of 2001 were similar to the results of 2000. We experienced significant increase of the LAI-value at N_{120}+PK kg/ha compared to the control, however, further increase in the rate of fertiliser resulted only in slight LAI-value growth.

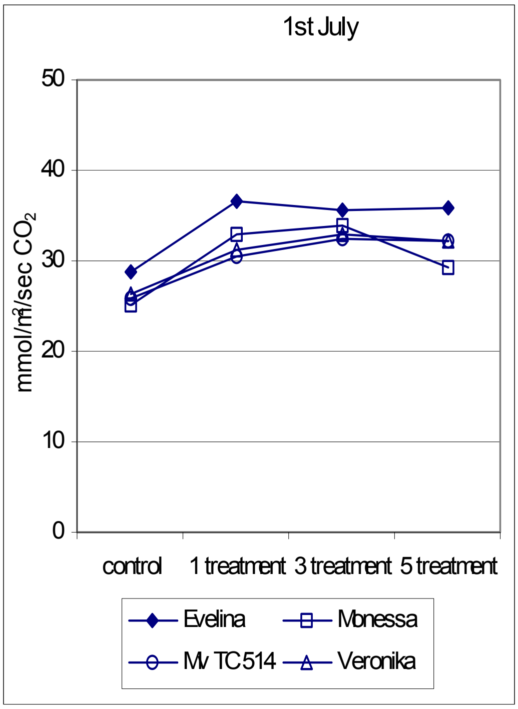
3.7. The effects of fertilisation on the photosynthetic activity of hybrids with different genetic background

In 1999, the maximum photosynthetic activity of most hybrids was detectable at N_{120}+PK and N_{200}+PK kg/ha active nutrient doses (figure 2). In the first three measurements, fertilisation significantly increased photosynthetic activity compared to the control in the average of the hybrids. There were no significant differences among the different fertilisation doses. In the fourth measurement, there were no significant differences among the values of the different treatments in the average of the hybrids examined.

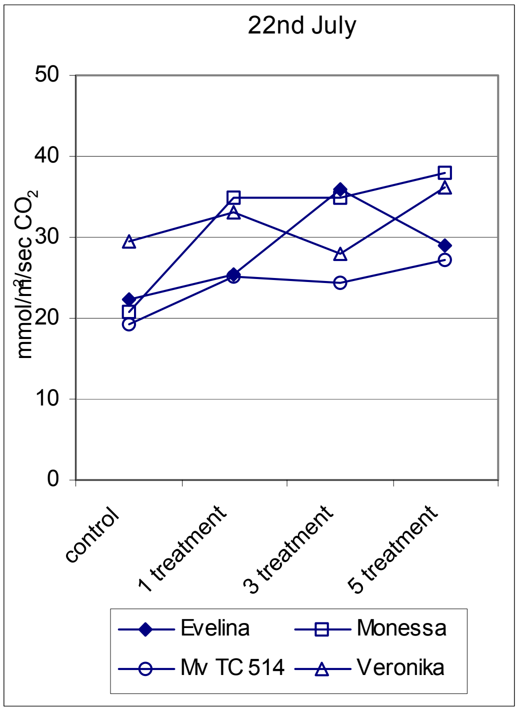
In 2000, the maximum photosynthetic activity was measured at N_{40}+PK kg/ha and N_{120}+PK kg/ha active nutrient doses (figure 3). In the first measurement, values measured in the N_{40}+PK kg/ha and N_{120}+PK kg/ha treatments were significantly higher than those of the control plots. In the second and third measurements, the control values were significantly lower than those of the fertilised plots.

Figure 2 The effect of fertilisation on the photosynthetic activity of hybrids 1999

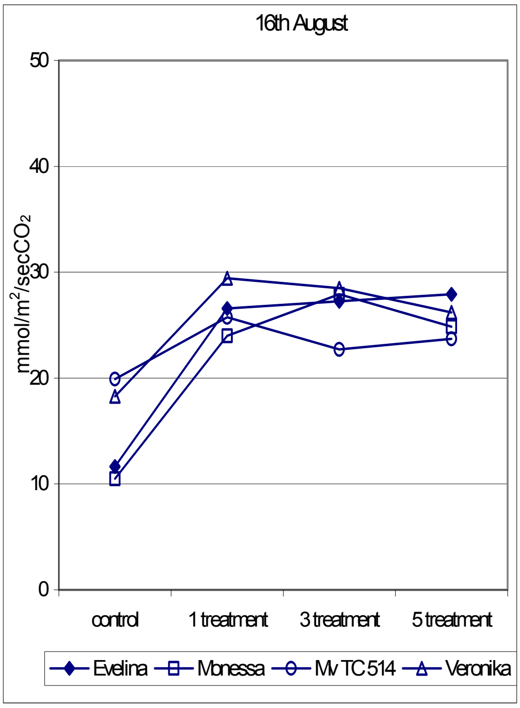
The $LSD_{5\%}$ values between the feriliser treatments stand for average of hybrids



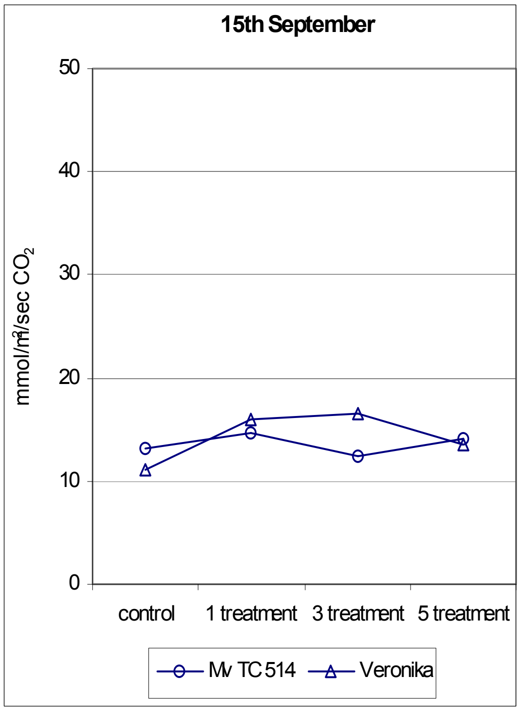
$LSD_{5\%}$=5.85



$LSD_{5\%}$=6.39



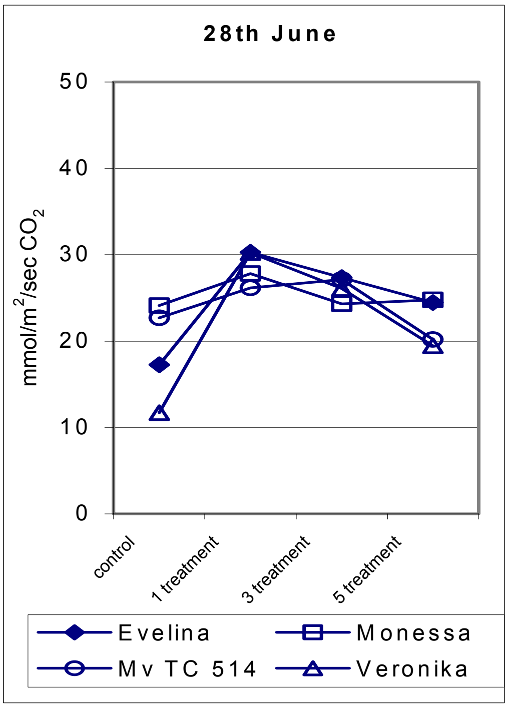
$LSD_{5\%}$=5.04



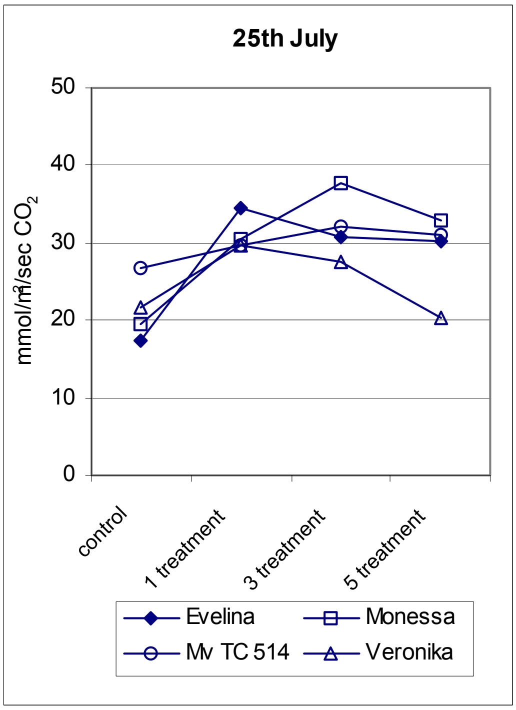
$LSD_{5\%}$=4.7

Figure 3 The effect of fertilisation on the photosynthetic activity of hybrids, 2000

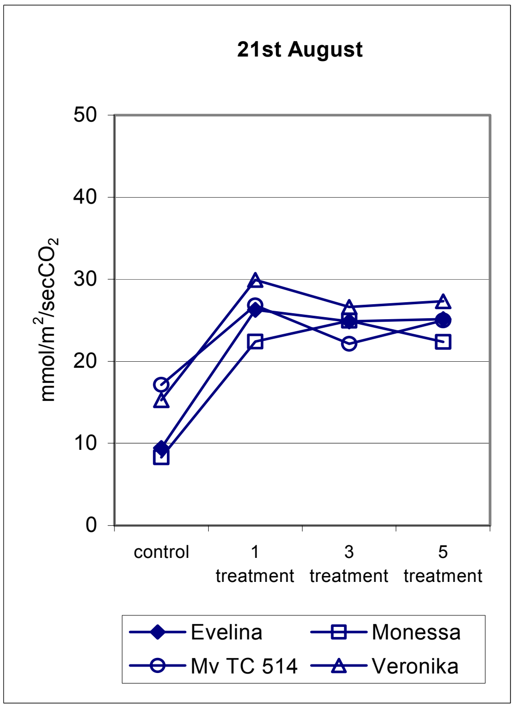
The $LSD_{5\%}$ values between the feriliser treatments stand for average of hybrids



$LSD_{5\%}$=5.58



$LSD_{5\%}$=7.9



$LSD_{5\%}$=5.3

4. New scientific results

1. The most important traits of the corn hybrids for the growing conditions can be determined by research carried out on arable land. The results obtained can be applied to other growing conditions, too.
2. Using variety-specific technology is the only way to produce corn efficiently and in an environmentally-friendly way.
3. The current climatic conditions of the year and the amount of rainfall can increase or in the case of unfavourable conditions, decrease the yield by 3-4 t/ha.
4. In corn production, increasingly newer hybrids are available which possess extremely high yield potential; however, weather extremeties and drought years are more frequent due to global warming. Therefore, we need to endeavour to better utilise the positive interactions among ecological, biological and agrotechnical factors. One of these important factors is the use of hybrids with good adaptation qualities, the other is the application of hybrid-specific technique.
5. Hybrids with good nutrient exploration and utilisation capacity (Filia SC, Mv TC 514) can be grown effectively at a low input level.
6. The newer corn hybrids are improved both in the natural nutrient exploration and utilisation capacity and in their reaction to fertilisers. While earlier the agroecological optimum was at 180 kg/ha active nutrient, it is presently 120 kg/ha active nutrient.
7. Hybrids can lose their water content the fastest during ripening when the application of fertilisers is optimal.
8. Taking into consideration the forecrop, the year effect, the nutrient supply and effectiveness and environmental protection, the $N_{40\text{-}120}$, $P_2O_{5\ 25\text{-}75}$ and $K_2O_{30\text{-}90}$ kg/ha active nutrient doses are satisfactory for corn hybrids.
9. A close connection exists between fertilisation and the nutrient content of the kernels. N fertilisation significantly increased the protein content of the kernel, while the starch content decreased. The oil content was different for the hybrids depending upon the year and the genotype. The oil content of some hybrids was constant (Monessa SC, Evelina SC), while it alternated for others during the two years of examination.
10. In most cases, the element contents (P, K, Mg) decreased due to fertilisation, except for N among the macroelements, Ca among the mesoelements, the amount of which

increased up to the N_{120}+PK kg/ha dose. Out of the microelements, the zinc content significantly decreased with the increase of fertiliser doses.

11. The relationship between the P_2O_5 fertilisation and the zinc content of the kernel is hybrid-specific. Zinc contents of DK 366 SC, Debreceni SC 351, Colomba SC and Filia SC did not change significantly as a result of fertilisation. The zinc content of Norma SC and DK 471 SC was significantly lower at N_{200}+PK active nutrient dose than without fertilisation.
12. NPK fertilisation had a slight effect on the fungal infection of the hybrids, while the traits of the grown hybrid effect infection to a greater extent as proved by statistical calculations. Among the different fertilisation treatments, there were significant differences in the infection of the hybrids. Infection by Fusarium spp. was significantly higher for Mv TC 514 and Evelina SC grown without fertilisation compared to that of Monessa SC and Veronika SC. Infection by Aspergillus spp. was higher for Evelina SC at N_{200}+PK active nutrient dose than that of the other three hybrids examined. Also, the infection by Fusarium spp. was higher for Mv TC 514 compared to that of Veronika SC.
13. The DON toxin occured in the highest amount, while T-2 was present in the smallest amount in the kernel samples out of the toxins examined (F-2, T-2, DON, DAS). Fertilisation did not have a significant effect on the toxin content and the differences of genotypes did not exceed the statistical margin of error.
14. The LAI-values obtained were dependent upon the hybrid and year effect. In favourable years the LAI-value reached 4.5-5 m^2/m^2. A close connection is justified between the LAI-value and the amount of yield. In a specific year, Mv TC 514 had the highest LAI-value (at the highest, N_{200}+PK rate) and its maximum yield (13.86 t/ha) was obtained at this fertiliser rate, too.
15. Under unfavourable growing conditions, the LAI-values were lower, too. LAI-values ranged between 3.32-3.95 m^2/m^2, which resulted in a 2-3 t/ha yield decrease depending on weather conditions.
16. The photosynthetic activities of the different hybrids differed, which is influenced by fertilisation also. The maximum photosynthetic activity was detected at N_{120}+PK kg/ha and N_{200}+PK kg/ha doses in favourable years, while in unfavourable years the maximum was at N_{40}+PK kg/ha and N_{120}+PK kg/ha.
17. We experienced the highest increase of photosynthetic activity at N_{40}+PK kg/ha dose compared to control, differences between the different fertiliser rates were lower.

18. For sustainable development we need to secure the fertility of soils, apply hybrid-specific technology and should endeavour to exploit the interactions between the production factors the best.

5. Results with practical application

1. One can utilise in practice the findigns of hybrid productivity, the natural nutrient exploration and utilisation capacity and the reaction to fertilisers.
2. According to experimental results, diverse technological variations can be applied in accordance with the intensity of the hybrids and the level of inputs, which ensure the protection of the environment besides efficiency.
3. Harmonical nutrient supplementation should be applied in corn production adjusted to the nutrient supply of the soil and the requirements of the hybrids, which ensures the conservation of soil fertility in the long run besides efficiency.
4. For the presently grown hybrids the application of N_{40-120}, $P_2O_{5\ 25-75}$ and K_2O_{30-90} is satisfactory depending upon the forecrop and the year.
5. When selecting the hybrid, farmers should prefer hybrids with better adaptability due to the aggravation of extreme weather conditions. Concerning agrotechnical factors, balanced nutrient supply, reasonable crop rotation and more professional plant protection are factors of primary importance.
6. The genetic traits of the hybrid, the growing conditions and the rate of fertiliser spread all have great effect on the moisture content of kernels at harvest. The rate and dynamics of water release during maturing is connected to the moisture content at harvest.
7. For farmers, besides the amount of yield, quality is important, which is greatly influenced by professional fertilisation.
8. The experimental results of the three-year research can be successfully adapted to areas with similar ecological conditions.

6. Scientific reports published in the field of the dissertation

I. Lectured scientific reports

1. **Jakab P**. (2001): A műtrágyázás hatása a kukoricahibridek termőképességére és trágyareakciójára. Debreceni Egyetem Agrártudományi Közlemények 1. Acta Agraria Debreceniensis. 2001/1 42-46. p.

2. **Jakab P**. (2002): A tápanyagellátás komplex vizsgálata a kukoricahibridek termesztésében. Debreceni Egyetem, Agrártudományi Közlemények (különszám) Acta Agraria Debreceniensis. 35-37. p.

3. **Jakab P - Zsoldos M**. (2002): Különböző évjáratok hatásának vizsgálata kukorica műtrágyázási kísérletekben. Debreceni Egyetem, Agrártudományi Közlemények (különszám) Acta Agraria Debreceniensis. 38-40. p.

4. **Jakab P**. (2002): Különböző genotípusú kukoricahibridek termőképességének és trágyareakciójának vizsgálata csernozjom talajon. II. Növénytermesztési Tudományos Nap Proceedings. 152-157. p.

5. **Jakab P**. (2002): A kukoricahibridek tápanyagellátásának racionalizálása tartamkísérletben. Tartamkísérletek, tájtermesztés, vidékfejlesztés. Nemzetközikonferencia I. kötet. Debrecen, Nyírlugos, Nyíregyháza, Livada (Sárköz, Románia). 2002. június 6-8. Szerk: Láng I., Lazányi J., Németh T. 233-237. p.

6. Futó Z .- Sárvári M .- **Jakab P**. (2002): Effect of fertilisation and sowing time on the yield of maize hybrids. Resources of the environment and sustained development. Nemzetközi Tudományos Konferencia. Analele Universitãtii Din Oradea, Tom VII. 2001. 77-84. p.

7. **Jakab P**. (2002): Összefüggés a tápanyagellátás és a kukorica hibridek termése között mészlepedékes csernozjom talajon. III. Alföldi Tudományos Tájgazdálkodási Napok. 2. kötet. Termesztéstechnológia. 46-51. p.

8. Sárvári M.-**Jakab P**. (2003): The effect of NPK fertilization on the protein, oil and starch content of maize hybrids on chernozem soil. Proceedings of the II. Alps-Adria Scientific Workshop. Trogir, Croatia.3-8 March 2003. 160-163. p.

II. Non lectured scientific reports

1. **Jakab P**. (1999): Effect of fertilization on the yield of maize hybrids. PhD hallgatók Második Nemzetközi Konferenciája. Miskolc. Proceedings. 99-104. p.

2. **Jakab P**. (1999): A kukoricahibridek termőképességének és trágyareakciójának vizsgálata. V. Ifjúsági Tudományos Fórum. Keszthely. 183-187. p.

3. **Jakab P**. (1999): A változatoknak megfelelően. Magyar Mezőgazdaság. Budapest. 54. évf. 17. szám. 10-11. p.

4. **Jakab P**. (2000): A termesztési tényezők hatása a kukorica termésére és minőségére. VI Ifjúsági Tudományos Fórum Keszthely. CD kiadvány.

5. Sárvári M. - **Jakab P**. (2000): Fajtaspecifikus kukoricatermesztési technológiák (1. rész). Agrárius Regionális Agrárinformációs Havilap. Debrecen. 2000/3. 10-11. p.

6. Sárvári M. - **Jakab P**. (2000): Fajtaspecifikus kukoricatermesztési technológiák (2. rész). Agrárius Regionális Agrárinformációs Havilap. Debrecen. 2000/4 8. p.

7. **Jakab P**. (2000): Összefüggés a kukoricahibridek termőképessége és trágyareakciója között. XLII. Georgikon Napok. Az agrár-termékpiacok és környezetük című kiadvány. I.kötet. 236-240. p.

8. Sárvári M. - **Jakab P**. - Futó Z. (2001): A korszerű kukoricatermesztés hatékonyságát befolyásoló tényezők I.rész. Agrárius Regionális Agrárinformációs Magazin. Debrecen. 2001/2 12-13. p.

9. Sárvári M. - **Jakab P**. - Futó Z. (2001): A korszerű kukoricatermesztés hatékonyságát befolyásoló tényezők II. rész. Agrárius Regionális Agrárinformációs Magazin. Debrecen. 2001/3 7-8. p.

10. Sárvári M. - **Jakab P**. - Futó Z. (2001): A korszerű kukoricatermesztés hatékonyságát befolyásoló tényezők III. rész. Agrárius Regionális Agrárinformációs Magazin. Debrecen. 2001/4 15-16. p.

11. Sárvári M. - **Jakab P**. - Futó Z. (2001): A kukoricahibridek alkalmazkodóképessége I. Magyar Mezőgazdaság. Budapest. 56. évf. 14. szám. 10-11. p.

12. Sárvári M. - **Jakab P**. - Futó Z. (2001): A kukoricahibridek alkalmazkodóképessége II. Magyar Mezőgazdaság. Budapest. 56. évf. 15. szám. 10-11. p.

13. Futó Z. - **Jakab P**. (2001): A kukoricatermesztés biológiai alapjainak jövőbeli kihívásai. Agrárius Regionális Agrárinformációs Magazin. Debrecen. 2001/6 14-15. p.

14. **Jakab P**. (2001): Az ökológiai és agrotechnikai tényezők hatása a kukoricahibridek produktivitására. Vidkéfejlesztés – Környezetgazdálkodás - Mezőgazdaság. Tudományos Konferencia. XLIII. Georgikon Napok Keszthely. 868-872. p.

15. **Jakab P**. (2001): A műtrágyázás hatása a kukoricahibridek termésére és beltartalmi paramétereire." Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában" című konferencia kiadványa. Gödöllő. 161-164. p.

16. Sárvári M. - **Jakab P**. - Futó Z. (2002): Fejlődő termesztéstechnológia. Magyar Mezőgazdaság. Budapest. 57. évf. 15. szám. 8-9. p.

17. Sárvári M. - **Jakab P**. - Futó Z. (2002): Fejlődő termesztéstechnológia II. Magyar Mezőgazdaság. Budapest. 57. évf. 16. szám. 8-9. p.

18. **Jakab P**. (2001): A kukoricahibridek tápanyagfeltáró képességének, valamint trágyareakciójának vizsgálata. "Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában" című konferencia kiadványa. Debrecen. 249-255. p.