

**Thesis of doctoral (Ph.D.) dissertation**

**THE EFFECT OF NUTRIENT-SUPPLY, HYBRID AND IRRIGATION ON THE YIELD  
AND NUTRIENT-UPTAKE DYNAMICS OF MAIZE (*ZEA MAYS L.*)  
ON A CHERNOZEM SOIL**

Marianna Sipos

Supervisors:

Dr. Imre Vágó  
CSc

and

Dr. János Kátai  
CSc



UNIVERSITY OF DEBRECEN  
Doctoral School Kálmán Kerpely

Debrecen  
2013

## **1. Preliminary fact and aims of the dissertation**

The basis for the new research work related to maize is on one hand that it is being produced on large crop land areas all over the world, has a high yield potential. On the other hand its utilization varies in many ways like as food, fodder or industrial raw material (Mengel, 1993).

It has to be noted that the conditions of crop production have changed due to the global climate change. This fact makes further research of crop production essential. The success and the efficiency of maize production are determined by – on their own already complex – ecological, biological and agrotechnical factors together (Mengel and Kirkby, 1982; Csathó et al., 1991; Debreczeni and Berecz, 2000; Huzsvai and Nagy, 2005; Nagy, 2007b). All these factors separately have a strong effect, but their complex approach is inevitable. It is possible to modify to a certain extent the ecological conditions of a given production site (like drought, amount of precipitation falling during the vegetation etc.) or even to limit their possibly negative effect by applying the appropriate measurements on time. With the knowledge of the conditions of a given production site it is important to emphasize the selection of the adequate variety or hybrid, because good genetic basis can be the key of the successful production. The always changing production site characteristics raise the demand and need the revision and check of the sometimes more-decades observations. All these make further research on this plant essential.

It is only possible to adapt our technology to the changing natural and production circumstances, in case the already available results are continuously completed with new ones about the yield, adaptation ability, just as the nutrient-uptake and the development of even newer genotypes. With regard to all these information production, nutrient management, irrigation, just as any other agrotechnical parameter can be adjusted to the demand of the given genotype.

From the aspect of the study of maize development knowledge on the nutrient uptake, especially that of the macronutrient uptake in the different vegetations is of main importance. Using this knowledge it can be possible to increase the efficiency of agrotechnical elements as a response to the extreme production conditions. It is possible to ensure under all circumstances the safe plant production by supplying the – during the vegetation continuously changing – demand of the plants, and by maintaining the optimal and balanced level of the production factors.

Long-term field experiments mean important means for gathering information regarding the sustainability of agricultural ecosystems.

We have set following aims in our research work:

1. To study the given crop-year, just as the effect and interactions between the **vegetation period** of different maize genotypes, **irrigation** and **nutrient-supply** on the **biomass- and grain-yield** of maize, the **nutrient stock of soil**, just as the **concentration of nutrients in the plant biomass**.
2. To study the **nutrient-uptake dynamics** during the vegetation on the basis of the nutrient stock of plant and soil, just as the amount of nutrients extracted from the soil by plant biomass.
3. Regarding the studied macronutrients to define and **draw conclusions for the practise** and that **aim a balanced, sustainable nutrient-supply that is adopted to the actual demand of plants**.

## **2. Methods of the research work**

The basis of the dissertation is a long-term irrigation and fertilization monoculture maize field experiment that has been set up Dr. János Nagy at the Látókép Experimental Station of the University of Debrecen, Centre for Agricultural- and Economical Sciences, Faculty of Agricultural, Food Sciences and Environment Management in 1984. Our experiments have been conducted during the vegetation in 2008 and 2009. In the more than two decades-experiment the change of the yield and other quality parameters of different maize hybrids are studied in case of the application of different fertilizer dosages and irrigation that ensure the optimal water-supply of plants.

The experimental treatments are the following: the main plots are irrigated and not irrigated treatments that dispose of the water amount from natural precipitation. The sub-plots mean the different maize hybrids with different long vegetation periods, while the sub-sub-plots are supplied with different nutrient-levels. Originally there are two water-supply, just as six nutrient-supply levels in case of a hybrid, so each hybrid has 48 plots altogether. The plant density is set to 70 000 plants per hectare by using a row distance of 76 cm, just as plant distance of 18 cm that means intensive production conditions. Each small-plot's size is 7.6 m<sup>2</sup> and they consist of two rows with a length of 5 metres each. The sizes of the gross and net plots are equal.

The soil of the experiment is a medium-heavy, loam texture calcareous chernozem type based on loess. The main parameters of the soil are shown in *Table 1*. Most of the parameters described in *Table 1*. are determined according to the standard methods of MÉM-NAK (1979) (Antal et al., 1979), while the total carbon-content of the soil is measured by the method interpreted by Nagy (2000). The plasticity acc. to Arany was measured using the method of Buzás (1988). We used the extractant 0.01 M CaCl<sub>2</sub> instead of the ammonium-lactate acetic acid (AL) that is much less aggressive than the AL and informs about the plant-available nutrient-amount at the moment of the sampling (Houba et al., 1990 and 1991), than other more aggressive soil-extractants. Regarding the nutrient-supply categories acc. to the MÉM-NAK advisory system the nitrogen-supply of the soil is sufficient, the phosphorous-supply is rather weak and the potassium-supply is middle. There are no visible signs of micro-nutrient deficiency.

The soil pH is slightly acidic, that is considered to be mostly favourable from the aspect of nutrient-mobilization and -uptake. The humus soil layer is about 70-90 cm. Its upper 30 cm layer has become leached due to the intensive production in the past several years, so it

doesn't content any significant lime-amount. Therefore under stressed conditions (drought, soil acidity) it is in some extent less able to buffer and compensate the negative effect of the unfavourable circumstances. The ground water layer is about 6-8 m below soil surface. The minimal water retention capacity is 27-29 V V<sup>-1</sup>%. This field represents the production circumstances of the chernozem soils in the region of the Hajdúság with excellent productivity.

Table 1.

The main parameters of the experimental soil

<i>Production site</i>	Debrecen-Látókép
<i>Soil type</i>	Calcareous chernozem
<i>Soil texture</i>	Loam
<i>Plasticity acc. to Arany (K<sub>A</sub>)</i>	39
<i>pH-H<sub>2</sub>O</i>	6.05
<i>pH-KCl</i>	5.41
<i>pH-CaCl<sub>2</sub></i>	5.73
<i>Hydrolytic acidity (y<sub>1</sub>)</i>	9.07
<i>Total C-content (%)</i>	1.89
<i>Humus-content (%)</i>	2.4
<i>Soil density (kg dm<sup>-3</sup>)</i>	1.19
<i>Total salt-content (m m<sup>-1</sup>%)</i>	0.05
<i>CaCO<sub>3</sub>-content (m m<sup>-1</sup>%)</i>	0
<i>AL-extractable P<sub>2</sub>O<sub>5</sub>-amount (mg kg<sup>-1</sup>)</i>	101.3
<i>AL-extractable K<sub>2</sub>O-amount (mg kg<sup>-1</sup>)</i>	232.4
<i>0.01 M CaCl<sub>2</sub>-extractable total N-content (mg kg<sup>-1</sup>)</i>	14.31

The experimental site consists of two parts: the half of it can be irrigated – in case it is needed – by a Valmont-type linear irrigation machine equipped with Wobbler low-pressure (2 bar) sprayers. On the other half of the experimental field plants dispose only of the water amount from the natural precipitation and the moisture-content of the soil. This enables us to follow and study the effects of the different crop-years, just as weather anomalies and we can find information about the extent of the achievable yield-increment in case of the satisfaction of plants' demands in the critical periods. On the other hand it is possible – for example in the studied crop-years – to study whether it is possible to increase the yield safety of the next crop-year by the adequate water-supply of the previous year.

We have chosen to study three different hybrids in the experiment. We have taken the length of the vegetation period of the different hybrids into account (FAO-number). We tried

to choose hybrids with different long vegetation periods, because according to our original hypothesis and knowledge there are differences in the both quantity and the dynamics of their nutrient-uptake. We have studied the hybrids Mv 251 (FAO 280), Mv Koppány (FAO 420), and Mv 500 (FAO 510).

Table 2.

The nutrient-treatment combinations of the field experiment expressed in fertilizer active substance

Treatment code	N (kg ha <sup>-1</sup> )	P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	K <sub>2</sub> O (kg ha <sup>-1</sup> )	Total (kg ha <sup>-1</sup> )
Control (0)	-	-	-	-
1	30	23	27	80
2	60	46	54	160
3	90	69	81	240
4	120	92	108	320
5	150	115	135	400

In this small-plot experiment the rate of the applied nutrients is fixed. The effect of macro-nutrient fertilization is studied – beside the control – at five levels with fixed 1.0:0.75:0.88 N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O rate. The above mentioned dosages are applied – according to the settings of the experiment – in the autumn by a mixed mineral fertilizer with a nutrient content of 16-12-14% active substance, that contain the nitrogen as a form of NH<sub>4</sub>NO<sub>3</sub>. The applied active substance amounts are described in Table 2.

Before the application of the mineral fertilizers the pre-crop – maize – residues are chipped and rotated into the soil by a plate disc. After the application of the mineral fertilizers they were rotated into the soil too, and afterwards the soil was ploughed in the autumn. In the springtime the soil was dragged. Parallel to the preparation of the seedbed the soil was disinfected as well. This was essential, because in monoculture maize production the western corn rootworm (*Diabrotica virgifera virgifera* LeConte) larvae potentially cause large damages that should be avoided. The applied chemical was Force 1,5 G micro-granulate soil disinfection substance in a dosage of 14 kg ha<sup>-1</sup>. During the vegetation post-emergent chemical, just as mechanical weed-control measurements were applied. The applied herbicide was Cambio in 2008 (3 dm<sup>3</sup> ha<sup>-1</sup>), while Laudis (2.2 dm<sup>3</sup> ha<sup>-1</sup>) in 2009. No significant infection symptoms of any plant disease or pests were observed in any of the investigated crop-years. Sewing dates were 22<sup>nd</sup> April 2008 and 15<sup>th</sup> April 2009. The plant shooting was a bit slower in 2008 (5<sup>th</sup> May), while it took only 10 days in 2009 (25<sup>th</sup> April).

The distribution of the fallen precipitation in 2008 was really favourable; therefore there was no need to apply any further irrigation on the appropriate plots. Considering the

water-supply of the previous years, just as the for the crop production essential water amount this enables us to draw – rational – consequences regarding the after-effect of the previous year irrigation. The distribution of the precipitation was less balanced in 2009, so each 25 mm of additional water amount was irrigated on the respective plots directly after shooting (29<sup>th</sup> April) and in the young vegetation (14<sup>th</sup> May).

Due to technical reasons the harvest of the hybrids – independent from their ripening group – was executed in the same time: in 2008 on 8<sup>th</sup> October, while in 2009 on 29<sup>th</sup> September. After determining the moisture content of the grain yield of each plot, yield amounts were calculated to 15% moisture content and are represented as per hectare results.

### **Plant sampling and analysis**

The dates of the plant sampling times were: 23<sup>rd</sup> May, 11<sup>th</sup> June, 23<sup>rd</sup> June, 9<sup>th</sup> July, 22<sup>th</sup> July, 13<sup>th</sup> August and 6<sup>th</sup> October in 2008, while 5<sup>th</sup> June, 26<sup>th</sup> June, 14<sup>th</sup> July, 28<sup>th</sup> July, 11<sup>th</sup> August and 23<sup>rd</sup> September in 2009. During the first sampling we cut the above-ground biomass of eight plants (in order to get enough and representative plant sampling material), while during the following sampling times we took only two plants from each plot.

After weighing the whole green biomass of the plant samples – that were the above ground biomass – we first chipped the samples and dried the plant material in the free air. The air dry samples were put into a drier machine afterwards where they were dried until their weight stayed the same. The amount of the dry matter was measured too. Then each sample was fine ground and mixed in order to get representative samples for the following analysis.

The phosphorous and potassium content of plant samples were measured after preparation with a cc. sulphuric acid digestion (Walinga et al., 1995). During the preparation we weighed 0.5 g of the dry and fine ground plant samples into a digestion tube and added 5 cm<sup>3</sup> cc. H<sub>2</sub>SO<sub>4</sub> to each of them. In order to have all organic substances digested we let the samples stand for the night. The next day we added 30 m/m% H<sub>2</sub>O<sub>2</sub> to them and under ventilation we started to boil the tubes as long as their colour has become clear. The received compound was let cool and was filled up to 50 cm<sup>3</sup> just as filtrated through an MN 640 W filter paper. For the determination of the potassium content of the samples this compound was appropriately diluted and measured by a flame emission photometer (Unicam SP90B). The phosphorous content was measured using the molybdenum blue photometry method described by (1988) at a wavelength of 880 nm. The nitrogen content of the plant dry matter was measured with a combustion method element analysis (Nagy, 2000).

## Soil sampling and analysis

We have taken soil samples three times in each vegetation: first in the beginning of the vegetation after sowing, second in the intensive nutrient uptake phase at the silking and third in the harvesting period. The time of the soil samplings were the following: 30<sup>th</sup> May, 22<sup>nd</sup> July and 10<sup>th</sup> October in 2008, while 5<sup>th</sup> June, 14<sup>th</sup> July and 23<sup>rd</sup> September in 2009. Soil samples were taken with a hand soil sampler that is recommended by the MÉM-NAK advisory system too. Each sample consisted of the soil amount gained by six sub-samples from the whole field of the plot in order to ensure the representative sampling and to have enough soil material for the analysis.

Soil samples were dried in the air first and afterwards fine ground with a special machine. Before all analysis they were dried until their weight remained the same. We used two extractant chemicals for the determination of the element content of the samples. First was the in the Hungarian professional advisory system widely used ammonium-lactate acetic acid soil extractant (AL). We determined the phosphorous-, potassium, calcium- and magnesium-content of the samples with this (Egner et al., 1960). This extractant is rather considered to be aggressive and informs about the nutrient amount in the soil that is plant available and ready to mobilise (Loch, 2006). Contrarily the soluble and easily exchangeable element-content was measured with the much less aggressive extractant 0.01 M CaCl<sub>2</sub> (Houba et al., 1990 and 1991). In case of the analysis with AL we weighed 5 g soil into plastic shaking bottles and added 50 cm<sup>3</sup> extractant to them. Afterwards the bottles were closed and shaken for two hours. The substance was filtered then through a filter paper type MN 640 W and filled up with distilled water to 50 cm<sup>3</sup>. The phosphorous content was measured with the above mentioned molybdenum blue photometry method. For the determination of the K-content first we had to eliminate the disturbing ions by adding oxalic acid. After 24 hours we measured the potassium-content with a flame emission photometer (Unicam SP90B). In case of the less aggressive extractant for nitrogen and potassium, the 0.01 M CaCl<sub>2</sub> we shook 5 g soil with 50 cm<sup>3</sup> of extractant for two hours. The substance was afterwards filtered through a filter paper (type MN 640 W) and filled up with aqua dest. to the given amount. We measured the different N- and P-forms directly from the filtered substance, just like the soil pH after letting the solution stand for 24 hours.

For the statistical analysis of the measurement data we used the three factor analysis of variance and linear regression analysis described by Sváb (1981). During the evaluation we used the Microsoft<sup>®</sup> Excel macro written by Tolner (Tolner et al., 2008). With this programme we have investigated the effects and interactions between the studied production factors. We

analysed the relationships between the nutrient-content of soil and plants with the regression analysis. The dynamics of plant production, just as the uptake of each nutrient was analysed with the computer programme Origin program 6.0.

### 3. Scientific results of the dissertation

1. The intensity of the green biomass and dry matter accumulation, just as the nutrient-uptake (Figure 1., 2., 3., 4., 5. and 6.) of the studied genotypes varies during the vegetation: in case of the early ripening hybrid a shorter, but more intensive nutrient uptake could be observed, while in case of the hybrids with longer vegetation the nutrient uptake was longer and its dynamics was less intensive.

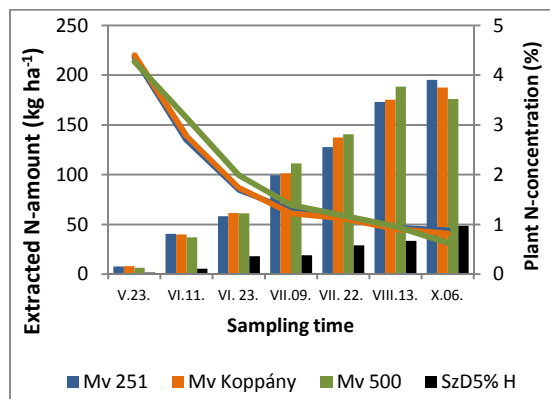


Figure 1.: Development of plant extracted N-amount and plant concentration during the vegetation as affected by the genotype (Debrecen-Látókép, 2008)

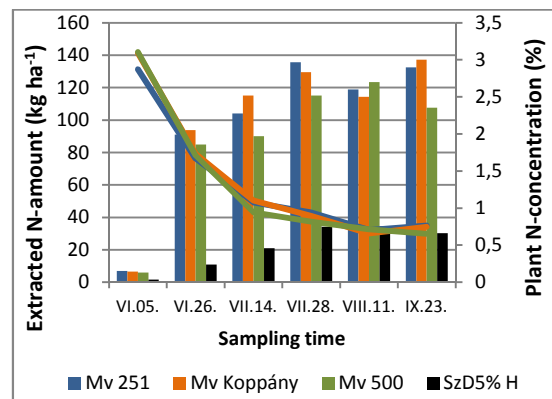


Figure 2.: Development of plant extracted N-amount and plant concentration during the vegetation as affected by the genotype (Debrecen-Látókép, 2009)

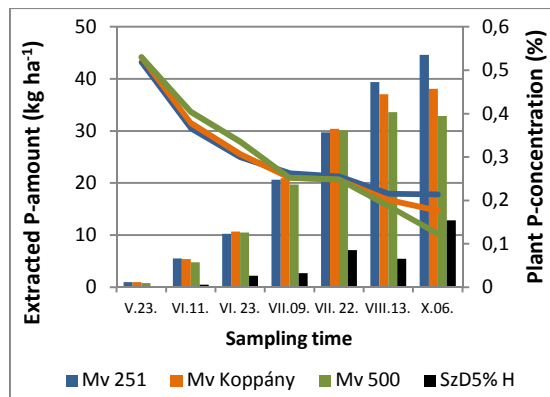
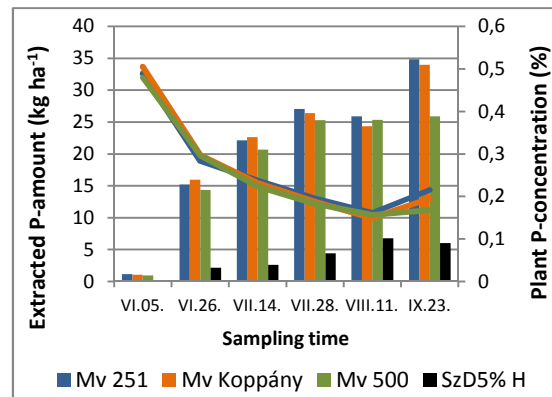


Figure 3.: Development of plant extracted P-amount and plant concentration during the vegetation as affected by the genotype (Debrecen-Látókép, 2008)



4. ábra: Development of plant extracted P-amount and plant concentration during the vegetation as affected by the genotype (Debrecen-Látókép, 2009)

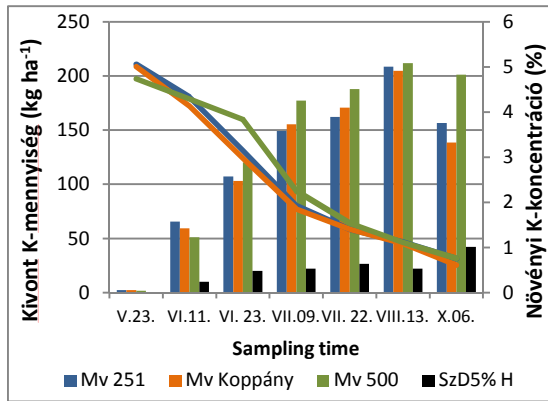


Figure 5.: Development of plant extracted K-amount and plant concentration during the vegetation as affected by the genotype (Debrecen-Látókép, 2008)

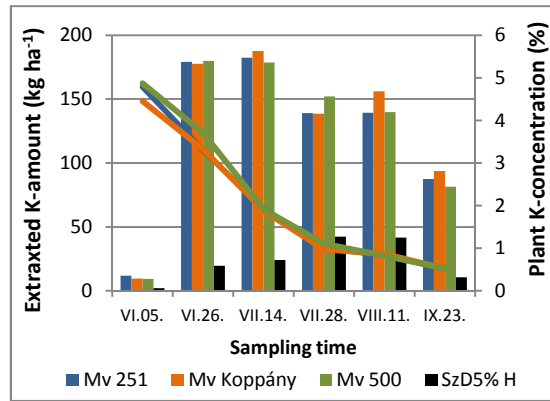


Figure 6.: Development of plant extracted K-amount and plant concentration during the vegetation as affected by the genotype (Debrecen-Látókép, 2009)

2. The mobilization and the uptake dynamics of the nutrients is mainly affected by the crop-year. In case of P (Figure 7. and 8.) the intensive uptake period is shortened by the severe water shortage. In case of the potassium even the half of the K-amount previously incorporated by the plants can be pumped back to the soil under such conditions (Figure 9. and 10.).

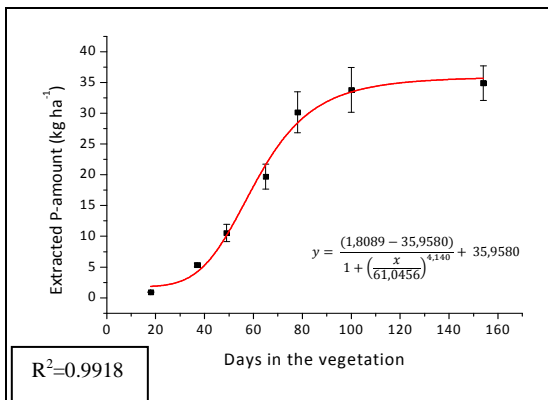


Figure 7.: Phosphorous uptake dynamics during the vegetation (Debrecen-Látókép, 2008)

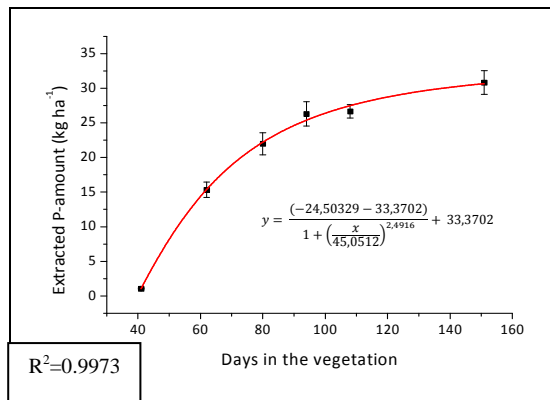


Figure 8.: Phosphorous uptake dynamics during the vegetation (Debrecen-Látókép, 2009)

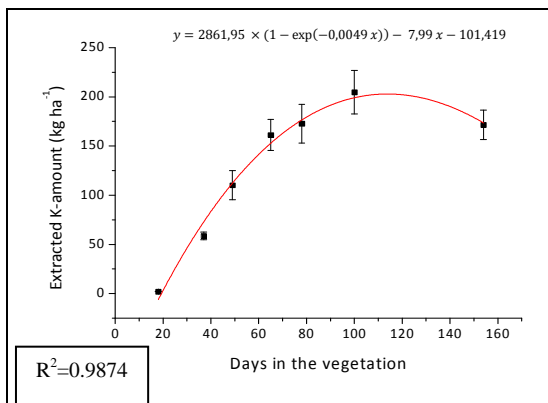


Figure 9.: Potassium uptake dynamics during the vegetation (Debrecen-Látókép, 2008)

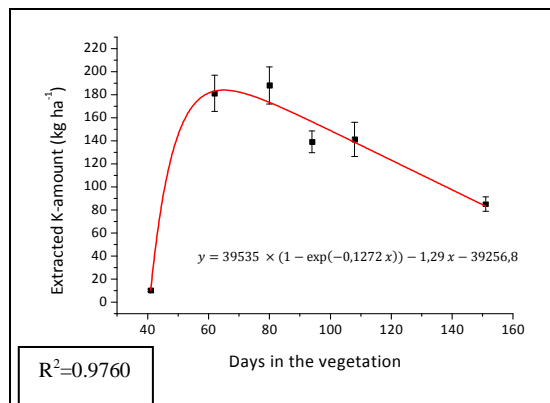
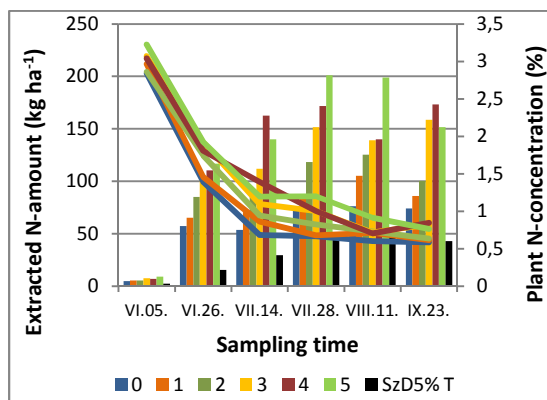
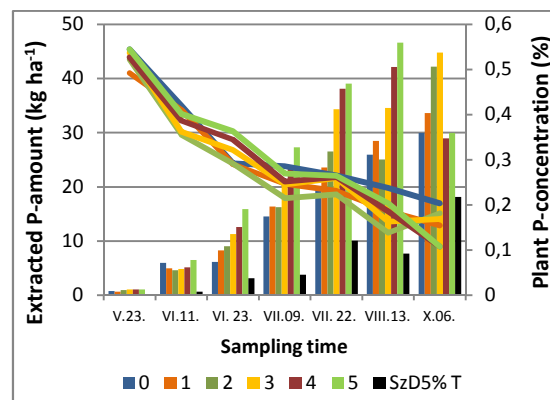


Figure 10.: Potassium uptake dynamics during the vegetation (Debrecen-Látókép, 2009)

3. **The silking and grain formation of the hybrid Mv 500 happened later;** in the crop-year with shortage in the water supply this time was drier and warmer than in case of the hybrids with shorter vegetation period. As a consequence of this Mv 500 could not compensate the limiting effect of the lack water supply during the grain filling and ripening phase.
4. In the treatments with higher N- (*Figure 11.*), P- (*Figure 12.*) and K-fertilization level plant **nutrient concentration** increased. However, during the vegetation the element concentration in the treatments with higher nutrient dosages decreased more intensive than in those of lower nutrient-supply levels.



*Figure 11.: Development of plant extracted N-amount and plant concentration during the vegetation as affected by the nutrient-supply levels (Debrecen-Látókép, 2009)*



*Figure 12: Development of plant extracted P-amount and plant concentration during the vegetation as affected by the nutrient-supply levels (Debrecen-Látókép, 2008)*

5. **The rate of nutrients** shall be determined according to the planned nutrient-supply level and the amount of precipitation/irrigation. In case of the studied fix nutrient rates we found additional N-mobilization from the nutrient stock of the soil (above the already utilized amount), while at higher nutrient supply levels the applied P-amount was not totally utilized by the plants in any of the studied crop-years. In the dry vegetation this latter phenomenon was observed for potassium too (*Figure 13., 14. and 15.*).

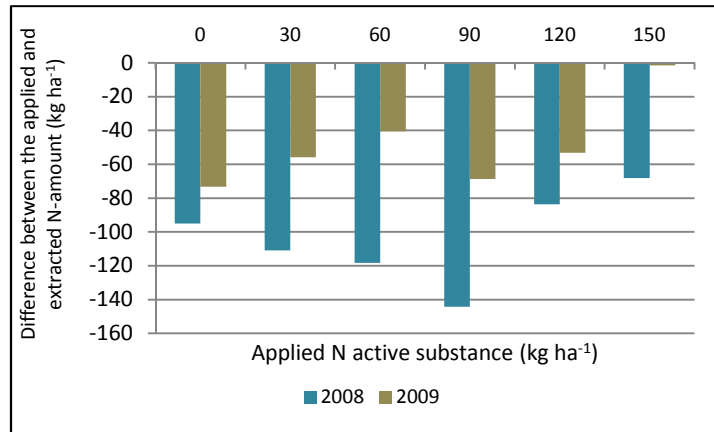


Figure 13.: The difference between the applied and extracted N-amounts at each nutrient-supply level

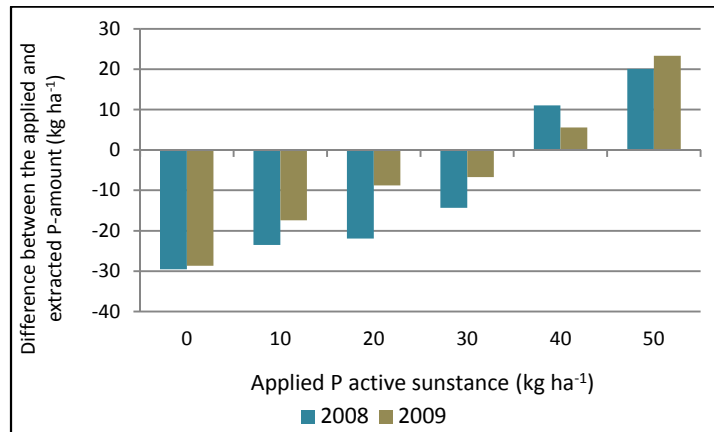


Figure 14.: The difference between the applied and extracted P-amounts at each nutrient-supply level

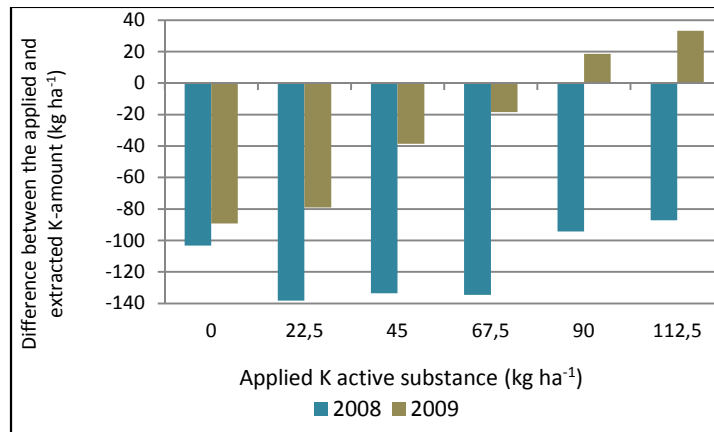


Figure 15.: The difference between the applied and extracted K-amounts at each nutrient-supply level

## 4. Useful results for the praxis

1. **In order to ensure the higher nutrient uptake parallel to the better water-supply** it is important to pay attention to the application of higher mineral fertilizer levels. In case of regular irrigation and a wet year with balanced water-supply it has to be considered that the higher nutrient uptake in the previous vegetations shall be completed with a higher level of nutrient-dosage in order to maintain the adequate nutrient-supply level of the soil.
2. Treatments that meet the requirements of **sustainable development** do not definitely match treatments with the highest yields. The highest nutrient-supply of the soil was observed in case of a middle nutrient-supply level with  $90 \text{ kg ha}^{-1} \text{ N} + \text{PK}$  mineral fertilizer active substance dosage (*Figure 13., 14. and 15.*).
3. Beside the continuous nutrient-supply it is **important to ensure the adequate water amount in all critical phenological phases** in order to ensure the optimal plant development. In case this is lack the resulted yield depression cannot be corrected by the plant in the rest of the vegetation.
4. In a crop-year with balanced water-supply the accumulation of plant green biomass (*Figure 16.*) and dry matter (*Figure 18.*) show a balanced tendency. Contrarily in dry vegetations the lack of water hinders the accumulation, and the change between the phase of accumulation and the decrease of the plant green biomass – due to the water loss and drying – can happen even 7-10 days earlier than in case of a wet crop-year (*Figure 17. and 19.*).

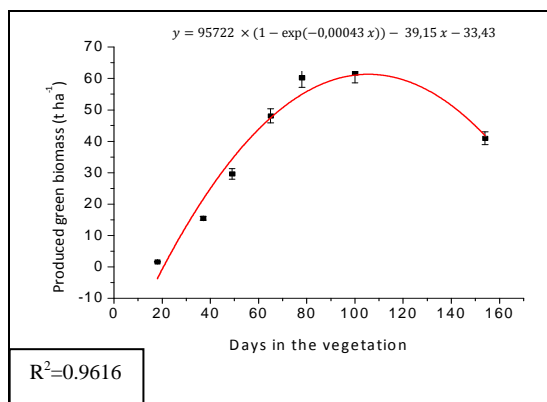


Figure 16.: Green biomass accumulation of maize in the vegetation of 2008 (average of treatments, Debrecen-Látókép)

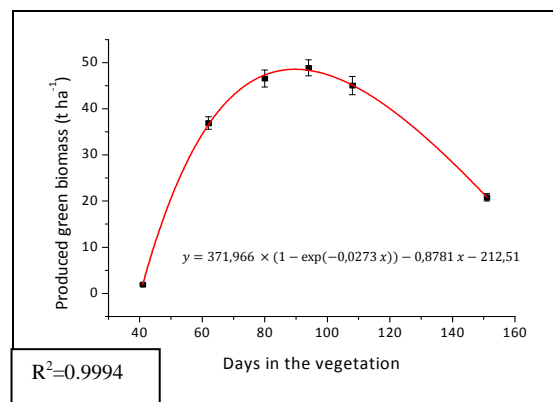


Figure 17. ábra: Green biomass accumulation of maize in the vegetation of 2009 (average of treatments, Debrecen-Látókép)

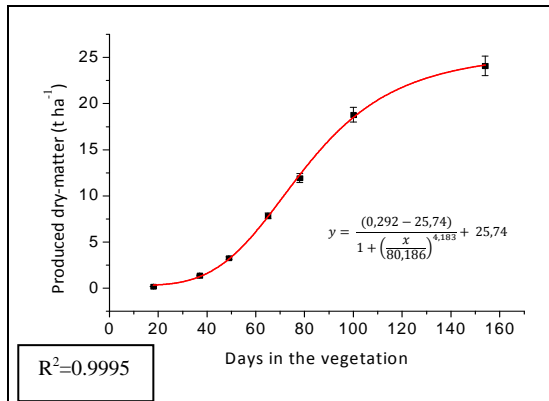


Figure 18.: **Dry matter accumulation of maize during the vegetation of 2008** (average of treatments, Debrecen-Látókép)

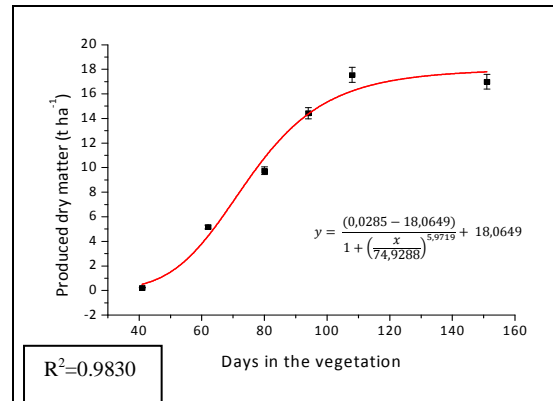


Figure 19.: **Dry matter accumulation of maize during the vegetation of 2008** (average of treatments, Debrecen-Látókép)

5. Beside the properties of the production site we have to take the length of the vegetation period by the choice of the produced hybrid. **The optimal dosages and application need to be adjusted to the phenophases of the chosen genotype.** In the period with the most critical water demand we suggest that the adequate water-supply shall be ensured in the last 10 days of June for early ripening hybrids, while in case of late-ripening ones this period is rather the first 10 days of July.
6. According to our results of this research work on a chernozem soil the mid-ripening **Mv Koppány** had reliable yield production in both wet and dry crop-year. The production of hybrids with FAO-numbers above 500 can be recommended only under intensive production circumstances, by continuously ensuring the nutrient and water demand of the plants.

## **5. Publications in the subject of the dissertation**

- Antal J. – Buzás I. – Debreceni B. – Nagy M. – Sipos S. – Sváb J.* (1979): A műtrágyázás irányelvei és üzemi számítási módszer. I. rész. N, P, K műtrágyázási irányelvek. MÉM Növényvédelmi és Agrokémiai Központ. Budapest. 1-47.
- Buzás I.* (szerk.) (1988): A talajok fizikai-kémiai és kémiai vizsgálati módszerei. Mezőgazdasági Kiadó. Budapest.
- Csathó P. – Lásztity B. – Sarkadi J.* (1991): Az „évjárat” hatása a kukorica termésére és terméselemeire P-műtrágyázási tartamkísérletben. *Növénytermelés* **40**. 4. 339-353.
- Debreczeni K. – Berecz K.* (2000): Effect of nutrient supply and site characteristics on NPK yield of different maize hybrids. *Acta Agronomica Hungarica*. **48**. 1. 51-63.
- Egner H. – Riem H. – Domingo W.* (1960): Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nährstoffzustandes der Böden. II. Chemische Extraktionsmethoden zur Phosphor und Kaliumbestimmung. *Kungl. Lantbrukshögsk. Ann.* **26**. 199-215.
- Houba V. J. G. – Novozamsky L. – Lexmond T. M. – Van der Lee J. J.* (1990): Applicability of 0.01 M CaCl<sub>2</sub> as a single extraction solution for the assessment of the nutrient status of soils and other diagnostic purposes. *Communications in Soil Science and Plant Analysis*. **21**. 2281-2290.
- Houba V. J. G. – Jászberényi I. – Loch J.* (1991): Application of 0,01 M CaCl<sub>2</sub> as a single extraction solution for evaluation of the nutritional status of Hungarian soils. *Debreceni Agrártudományi Egyetem Tudományos Közleményei*. XXX. 85-89.
- Huzsvai L. – Nagy J.* (2005): Effect of weather on maize yields and the efficiency of fertilization. *Acta Agronomica Hungarica*. **53**. 1. 31-39.
- Loch J.* (2006): Tápanyagvizsgálati módszerek értékelése. In: *Loch J. és Lazányi J.* (szerk.) (2006): A tápanyag-gazdálkodást segítő talajvizsgálati módszerek alkalmazása a Nyírség homoktalajain. Nyíregyháza. 51-77.
- Mengel K.* (1993): Impact of intensive agriculture on resources and environment. In: *Fragoso M. A. C. és van Beisichem M. L.*: Optimization of Plant Nutrition. Kluwer Academic Publishers. Hollandia. 613-617.
- Mengel K. – Kirkby E.A.* (1982): Principles of Plant Nutrition. International Potash Institute. Bern. 655.
- Nagy J.* (2007b): Kukoricatermesztés. Akadémiai Kiadó. Budapest.
- Nagy P. T.* (2000): Égetéses elven működő elemanalizátor alkalmazhatósága talaj- és növényvizsgálatoknál. *Agrokémia és Talajtan*. **49**. 3-4. 521-534.
- Sváb J.* (1981): Biometriai módszerek a kutatásban. Mezőgazdasági Kiadó. Budapest.

*Tolner L. – Füleky Gy. – Aydinalp C. (2008): Öntözés talajszennyező hatásának igazolása valódi ismétlést nem tartalmazó megfigyelési adatok segítségével. VIII. Magyar Biometriai és Biomatematikai Konferencia. Budapest.*

*Walinga J. – van der Lee J. J. – Huoba V. J. G. – van Vark W. – Novozamsly I. (1995): Plant analysis manual. Kluwer Academic Publishers. Dordrecht – Boston – London. A1/31-33.*

## **6. Publications of the candidate in the subject of the dissertation**

### Hungarian book chapter:

*Sipos M. – Vágó I. (2008): A talaj tápanyag-készlete In. Talajtan, talajökológia Szerk.: Kátai J. Talajtan, talajökológia. DE AMTC. Debrecen.*

### Foreign language scientific full-papers in Hungarian reviewed journals:

*Sipos M. – Balla Kovács A. – Oláh Zsuzsanna Á. (2008): Effect of nitrogen-supply, nickel-contamination and liming on the chemical composition of perennial ryegrass (*Lolium perenne L.*). Cereal Research Communications. 36. 447-450 p. VII. Alps-Adria Scientific Workshop. Stara Lesna.*

*Balla Kovács A. – Sipos M. – Kremper R. (2008): Influence of bio- and chemical fertilization on nitrate accumulation, phosphorus and calcium content in lettuce (*Lactuca sativa L.*). Cereal Research Communications. 36. 555-558. p. VII. Alps-Adria Scientific Workshop. Stara Lesna.*

*Kincses I. – Filep T. – Kremper R. – Sipos M. (2008): Effect of nitrogen fertilization and biofertilization on element content of parsley. Cereal Research Communications. 36. 571-574. p. VII. Alps-Adria Scientific Workshop. Stara Lesna.*

*Nagy P. T. – Sipos M. – Szabó Z. – Nyéki J. (2008): „Érdi Bőtermő” Sour Cherry Response to Nitrogen and Boron Foliar Fertilization. Journal of Agricultural Sciences. Debrecen. 193-197. p.*

*Balla Kovács A. – Vágó I. – Kremper R. – Sipos M. – Tállai M. (2008): The Influence of Chemical Biofertilizers on the Yield, Nitrogen, Phosphorous and Potassium Content of Lettuce (*Lactuca sativa L.*) in a two-year Greenhouse Experiment. Journal of Agricultural Sciences. Debrecen. 43-48. p.*

*Kincses I. – Kremper R. – Sipos M. (2008): Investigation of the after effect of bacterium fertilization in pot experiment. (Jubileum Nagyvárad) 6th International Scientific Symposium, „Natural Resources and Sustainable Development. Results and Practise of the Bologna process. Debrecen, 2008. október 3. Journal of Agricultural Sciences Acta Agraria Debreceniensis Supplement 23-28.*

*Sipos M. – Kincses I. – Berta Szabó E. (2009): Study of the effect of limiting production factors – hybrid, nutrient-supply level and irrigation – on the yield and starch-content of maize (*Zea mays L.*) Cereal Research Communications. 37. 145-149 VIII. Alps-Adria Scientific Workshop. Neum.*

*Nagy P. T. – Sipos M. – Szabó Z. – Soltész M. – Nyéki J. (2009): The effect of climatic anomalies on the nutrient supply of fruit plantation (Minireview). International Journal of Horticultural Science. 15. (1-2). 111-116.*

Scientific full-papers in reviewed Hungarian journals:

- Sipos M. (2008): A nikkell-szennyezés, a nitrogén-trágyázás és a kalcium-karbonát adagolás hatása az angol perje (*Lolium perenne L.*) elemtartalmára. Agrártudományi Közlemények. 30. 85-92.
- Sipos M. (2009): A hibrid, a tápanyag-ellátás és az öntözés hatása a kukorica (*Zea mays L.*) betakarításkori szemnedvesség-tartalmára, illetve keményítő-tartalmára. Agrártudományi Közlemények. 35. 89-94.
- Sipos M. (2009): A kukorica (*Zea mays L.*) termésének, valamint néhány beltartalmi értékének vizsgálata a hibrid, a tápanyag-ellátás és az öntözés függvényében. Agrokémia és Talajtan. 58. 1. 79-90.
- Sipos M. (2009): A kukorica (*Zea mays L.*) magnézium-felvételi dinamikája mezőszégi talajon. Agrártudományi Közlemények. 42. 83-89.
- Balláné Kovács A. – Sipos M. (2009): Az ammónium-nitrát és a Microbion UNC baktériumtrágya hatása a torna (*Armoracia macrocarpa*) tápelemtartalmára. Kertgazdaság. 41. 4. 3-11.

Foreign language, reviewed conference publications:

- Sipos M. – Vágó I. – Balla-Kovács A. – Kincses I. (2007): Die Wirkung von Stickstoffversorgung, Schwermetallbelastung und Kalkung auf die Trockensubstanzproduktion des Englischen Weidelgrases (*Lolium perenne L.*). Erdei Ferenc IV. Tudományos Konferencia, 2007. aug. 27-28. Kecskemét. 184-187. p.
- Sipos M. – Vágó I. (2007): The effect of nitrogen supply, liming and nickel contamination on the productivity of ryegrass (*Lolium perenne L.*) in a greenhouse experiment. Joint International Conference on Long-term Experiments, Agricultural Research and Natural Resources. 31st May – 1st June. Debrecen-Nyírlugos. Lecture. 163-169. HU-ISBN: 978-963-473-054-5
- Vágó I. – Kátai J. – Sipos M. – Balla Kovács A. – Kincses I. (2008): Changes of yield amount and some content parameters of strawberry (*Fragaria ananassa*) as affected by potassium and magnesium fertilization. International Symposium “Risk Factors for Environment and Food Safety” Oradea, Romania. 317-322. p.
- Kincses I. – Sipos M. (2008): The effect of bacteria fertilizers on the nitrogen amount extracted by the yield of perennial ryegrass (*Lolium perenne L.*) on different soil types. International Symposium “Risk Factors for Environment and Food Safety” Oradea, Romania. 121-126. p.
- Sipos M. – Balla-Kovács A. – Kincses I. – Nagy P. T. (2009): Investigation of effects and interactions between nutrient-supply, irrigation, hybrid and zinc-uptake of maize (*Zea mays L.*) Trace Elements in the Food Chain. Vol. 3. Deficiency or Excess of Trace Elements in the Environment as a Risk of Health. 317-321.

- Sipos M. – Nagy P. T. – Balla Kovács A. – Kincses I. – Vágó I.* (2009): Interactions between long-term fertilization, hybrid and irrigation on the calcium-uptake dynamics of maize (*Zea mays L.*). Erdei Ferenc V. Tudományos Konferencia. Kecskemét. 2009. 09. 03-04. 3.kötet. 1397-1401. ISBN: 978-963-7294-73-0.
- Sipos M. – Kincses S.né – Nagy P. T. – Balláné Kovács A. – Bakó A.* (2009): Die Wirkung von mineralischer Düngung auf die Magnesiumaufnahme des Maises (*Zea mays L.*). Erdei Ferenc V. Tudományos Konferencia. Kecskemét. 2009. 09. 03-04. Erdei Ferenc V. Tudományos Konferencia. Kecskemét. 2009. 09. 03-04. 1.kötet. 394-398. ISBN: 978-963-7294-73-0.
- Sipos M. – Vágó I. – Nagy P. T. – Balláné Kovács A. – Kincses S.né* (2009): The effect of long-term fertilization on the manganese uptake dynamics of maize (*Zea mays L.*). LI. Georgikon Tudományos Napok. Keszthely. 2009. 10. 01. 832-837.
- Sipos M. – Vágó I.* (2009): The effect of and interactions between hybrid, nutrient-supply and irrigation on the calcium and magnesium-uptake dynamics of maize (*Zea mays L.*). In: International Symposia Risk Factors for Environment and Food Safety & Natural Resources and Sustainable Development, Faculty of Environmental Protection, November 6-7 Oradea 2009. Symposium CD 329-337.
- Vágó I. – Sipos M.* (2009): Investigation of production factors on the yield and starch content of maize (*Zea mays L.*) on a chernozem soil in Hungary. Ukrán-magyar TÉT bilaterális pályázat keretében megrendezett konferencia. Debrecen. In print.
- Balla-Kovács A. – Vágó I. – Sipos M. – Filep T.* (2009): Effects of different N and S doses on Mn and Zn content of garden bean (*Phaseolus vulgaris L.*). Trace Elements in the Food Chain. Vol. 3. Deficiency or Excess of Trace Elements in the Environment as a Risk of Health. 282-286.
- Nagy P. T. – Kincses I. – Sipos M. – Nyéki J. – Szabó Z.* (2009): Study of the effects of a complex fertilizer and a biostimulator on trace element contents of leaf and fruit of sweet cherry (*Prunus Avium*). Trace elements in food chain Vol. 3. Deficiency or excess of trace elements in the environment as a risk of health. Eds.: M. Szilágyi, K. Szentmihályi, pp. 307-311.
- Kincses I. – Nagy P. T. – Sipos M.* (2009): Effect of bacteria fertilizers on plant extracted Zn and Cu content of ryegrass (*Lolium perenne*) at different types of soil Trace Elements in the Food Chain. Vol. 3. Deficiency or Excess of Trace Elements in the Environment as a Risk of Health. 357-361.
- Nagy P. T. – Sándor Zs. – Kincses I. – Sipos M. – Nyéki J. – Szabó Z.* (2009): Effects of different groundwater applications on nutrient contents of soil in an integrated apple orchard in eastern Hungary. Erdei Ferenc V. Tudományos Konferencia. Kecskemét. 2009. 09. 03-04. 3.kötet. 1372-1376. ISBN: 978-963-7294-73-0.
- Nagy P. T. – Kincses I. – Sipos M. – Nyéki J. – Szabó Z.* (2009): Effects of different groundcover applications on available easily soluble nitrogen forms of soil in an integrated

apple orchard in east Hungary. In: International Symposia Risk Factors for Environment and Food Safety & Natural Resources and Sustainable Development, Faculty of Environmental Protection, November 6-7 Oradea 2009. Symposium CD 436-441.

Hungarian, reviewed conference publications:

*Balláné Kovács A. – Sipos M. – Kremper R. – Vágó I.* (2009): A különböző formájú műtrágyák és a Microbion UNC baktériumtrágya hatása a torma (*Armoracia macrocarpa*) N, P, K, Ca és Mg-tartalmára. Tudomány és oktatás. Agtedu 2009 Konferencia. Kecskemét. ISSN: 1586-846x; ISBN: 978-963-7294-77-8. 37-42.

*Nagy P. T. – Sipos M. – Vágó I. – Szabó Z. – Nyéki J.* (2009): A hazai gyümölcsstermesztés jelenlegi tápanyag-utánpótlási gyakorlatának értékelése. Tudomány és oktatás. Agtedu 2009 Konferencia. Kecskemét. ISSN: 1586-846x; ISBN: 978-963-7294-77-8. 90-95

*Vágó I. – Balláné Kovács A. – Sipos M. – Kátai J. – Nagy P. T.* (2009): Mátrixhatások a talajextraktumok bórtartalmának spektrofotometriás mérésénél. Tudomány és oktatás. Agtedu 2009 Konferencia. Kecskemét. ISSN: 1586-846x; ISBN: 978-963-7294-77-8. 136-141.

*Nagy P. T. – Sipos M. – Szabó Z. – Nyéki J.* (2009): Biostimulátorok használata cseresznye ültetvények tápanyag-ellátásában. LI. Georgikon Napok. 2009. 648-654.

*Kincses S.né – Sipos M. – Kremper R.* (2009): Baktériumtrágyák hatása az angolperje (*Lolium perenne*) terméssel kivont nitrogén- és foszfor mennyiségére különböző típusú talajon. Erdei Ferenc V. Tudományos Konferencia. Kecskemét. 2009. 09. 03-04. 3.kötet. 1258-1262. ISBN: 978-963-7294-73-0.

*Szabó A. – Tomócsik A. – Sipos M. – Nagy P. T. – Makádi M.* (2010): Biogáz előállítás fermentációs maradékainak hasznosíthatósága a növény táplálásban. Zöldenergia, földhő és napenergia hasznosítása a hőtermelésben. Konferenciakiadvány. Károly Róbert Főiskola. Kutató, Fejlesztő Központ. Gyöngyös. 98-101.

*Sipos M. – Szöllősi N. – Nagy P. T. – Sándor Zs. – Balláné Kovács A. – Vágó I.* (2010): A trágyázás tartamhatása a talaj urán-felhalmozódására tartamkísérletben. Szeged, Talajtani Vándorgyűlés, 2010. szeptember. In print.

Hungarian abstract:

*Sipos M. – Kincses I. – Nagy P. T.* (2008): A talajtakarás szerepe fiatal, nem termő cv. Vilmos körtefák makro-tápelem-felvételére. A Tudomány Ünnepe – Fiatal Kutatók az Élhető Földért Konferencia. Poszter. Budapest.

<http://www.agrarkutatas.net/absztraktok/elem/id/75/A-talajtakarás-szerepe-fiatal,-nem-termő-cv--Vilmos-körtefák-makrotápelem-felvételére>

Foreign language abstract:

*Sipos M.* (2009): Contamination of agricultural soils by mineral fertilization. II. Nachwuchswissenschaftlerforum des JKI. Berlin-Dahleim. 2009. 11. 17-19. In print.

Documentary publication:

*Bai A. – Sipos M.* (2009): A növénynevelés és az agrotechnika szerepe a bioetanol versenyképességében. *Bioenergia*. 4. 1. 15-20.

Publications that are not directly related to the field of the research:

*Sipos M.* (2008): Climate change, food crisis and effectivity of energy-use: Is the whole thing about idleness or are only the problems too complicated? Winner prize of the FAO REU Essay Contest

[http://www.fao.org/world/regional/reu/docs/marianna\\_sipos.pdf](http://www.fao.org/world/regional/reu/docs/marianna_sipos.pdf)

*Sipos M.* (2009): Élelmiszer vagy nyersanyag – a mezőgazdasági termékek hasznosításának dilemmája. Tudomány és oktatás. Agtedu 2009 Konferencia. Kecskemét. ISSN: 1586-846x; ISBN: 978-963-7294-77-8. 108-112.

*Sipos M. – Vágó I. – Kratz S. – Schnug E.* (2010): Uran in Düngemitteln und dessen Verbleib in der Umwelt - Teil 2: Grund-, Oberflächen- und Mineralwässer. XII. NTN. Gyöngyös. 2010.03.25-26. Programme 127.

*Sipos M.* (2010): A kukorica keményítő-hozamát befolyásoló tényezők vizsgálata a jobb etanol-kihozatal érdekében. Zöldenergia, földhő és napenergia hasznosítása a hőtermelésben. Konferenciakiadvány. Károly Róbert Főiskola. Kutató, Fejlesztő Központ. Gyöngyös. 90-93.

*Vágó I. – Sipos M. – Tolner L. – Schnug E.* (2010): Uran in Düngemitteln und dessen Verbleib in der Umwelt - Teil 1: Boden. XII. NTN. Gyöngyös. 2010.03.25-26. Programme 126.

*Sipos M. – Nagy P. T. – Szabó A. – Kátai J. – Vágó I.* (2010): Uranium in fertilizers and their retention in ground and stream waters. Natural and artificial ecosystems in the Somes - Cris - Mures - Tisa river basin. International Conference, Arad, 07-08. May. Book of Abstracts p. 151.

*Földesi M. – Sipos M. – Szabó A. – Vágó I.* (2010): Uranium in fertilizers and their retention in the soil. Natural and artificial ecosystems in the Somes - Cris - Mures - Tisa river basin. International Conference, Arad, 07-08. May. Book of Abstracts p. 140.