# THE EFFECT OF AND INTERACTIONS BETWEEN HYBRID, NUTRIENT-SUPPLY AND IRRIGATION ON THE CALCIUM AND MAGNESIUM-UPTAKE DYNAMICS OF MAIZE (*ZEA MAYS L.*)

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***Abstract***
*Maize is a worldwide and even in Hungary dominant plant that is used different ways. According to nowadays plant production principles it is important to investigate and optimize its production site specific, regarding each of its production factors, such as nutrient supply, irrigation, the chosen hybrid and other technical elements.*
*In confines of the long-term maize monoculture field experiment at Debrecen- Látókép we investigated the effect of nutrient-supply and irrigation on the quantity and quality parameters of different hybrids. In this paper we introduce the first year (2008) results regarding the calcium and magnesium uptake dynamics of whole plants, resp. the effect of the investigated three production factors on the soil pH.*
*We have chosen three maize hybrids – that have been bread in Martonvásár – for our investigations. The effect of macro-nutrients is investigated in this experiment on five levels besides control treatment. The half of the experimental area can be irrigated during the vegetation period – whenever it is needed – by linear irrigation equipment, but on the other half there is no additional water amount available for plants.*
*We took plant and soil samples in different and from the aspect of plant development significant times. The soil pH-value was measured in a 0.01 M $CaCl_2$-extraction that is characteristic to the nutrient uptake circumstances in the soil. The element content of plants was measured by AAS method. By the way – beside element concentration – we calculated the during the vegetation totally and periodically extracted calcium and magnesium amount. We used 3-way ANOVA and correlation analysis to evaluate our results statistically as well.*
*We found different effects of different production factors during the vegetation period. Generally it can be stated that all of them influenced the nutrient uptake in some way. Regarding the totally taken up nutrient amount in both cases, it can be stated that the difference between the length of hybrids' vegetation period had the greatest effect. Regarding the nutrient content, in each sampling period the affecting factors have been different. We could also reveal some interactions between the surveyed factors. In this paper we introduce our results in tables and figures as well.*

**Keywords:** nutrient-supply, hybrid, irrigation, calcium, magnesium, maize

## INTRODUCTION

Maize is a worldwide dominant and important crop in human consumption, animal husbandry or even in the energetic and industrial use.

The natural situation of Hungary makes us possible to produce crops that are rentable in countries southern from us, but no more in the northern countries. Maize is such a crop in the country, that belongs to the main producing countries in Europe (Fageria et al., 1991).

Crop yield is mainly determined by the biological quality of the crop, just as the production circumstances, like production site, ecologic parameters and weather, nutrient- and water-supply (Kreuz, 1977; Huzsvai – Nagy, 2005; Megyes et al., 2005; Kátai et al., 2006). During the intensive nutrient uptake period the amount of plant available nutrients and water has a basic relevance, because these factors mean the bottleneck of plant development.

In Hungary the nutrient supply of plants is mainly appied by mineral fertilization. There are many results in the agricultural fertilization literature, that confirm that among production factors fertilization, resp. nutrient supply has the most yield increasing effect. Fertilization can even increase yield by approximately 30% (Berzsenyi – Győrffy, 1995).

Calcium plays many roles in plant life, like activator of numerous enzymes, in buffering systems, stabilisation of cells, regulation of colloids etc. (Bergmann – Neubert, 1976; Buzás, 1983; Loch – Nosticzius, 2004).

Magnesium also has many specific functions in plant physiology. Among others it is an important part of chlorophyll, beside this, in enzymatic processes, as activator, or in nitrogen cycle as well. (Bergmann – Neubert, 1976; Buzás (ed.), 1983).

Many production factors affect the uptake of calcium resp. magnesium, as well, just like cropping year, weather conditions, hybrid (Rastija et al., 2008), competing ions, soil properties(FiztPatrick, 1986), nutrient supply, water management, etc. (Olness et al., 2002; Osemwota et al., 2007).

## MATERIALS AND METHODS

Within the confines of a more, than two decades long maize monoculture field experiment at Debrecen-Látókép, Hungary changes in the yield and different quality parameters of maize hybrids have been investigated in function of ascendant nutrient dosages and irrigation. Among others we study the effects and interactions between three production factors: maize hybrid, nutrient-supply levels and irrigation on the calcium- and magnesium content and uptake dynamics of plants. In this paper we introduce the first year (2008) results of our investigations.

The experiment was set up on calcareous chernozem soil, based on loess with high buffering capacity that represents the soils with good fertility in the region Hajdúság. The upper soil level is leached due to the intensive production; therefore it doesn't contain any notable amount of $Ca^{2+}$. The size of each plot is 7.6 $m^2$, the size of the gross and net plot is equal. There are 70.000 plants per hectare that means intensive production circumstances. Each treatment combination is set up in four replications. Fertilizers with fixed 1.0 : 0.75 : 0.88 N : $P_2O_5$ : $K_2O$ rates are added on five levels – beside control treatment: 30:23:27and its multiples to 150:115:135 kg $ha^{-1}$ active substance. Nutrient treatment dosages are shown in *Table 1*.

*Table 1.*

The annually applied nutrient dosages and their codes in the experiment

| Treatment code) | N (kg $ha^{-1}$) | $P_2O_5$ (kg $ha^{-1}$) | $K_2O$ (kg $ha^{-1}$) | Total (kg $ha^{-1}$) |
|---|---|---|---|---|
| **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 |

These fertilizer dosages are applied in the autumn period by 'Kemira Power' mixed fertilizer that contains 16-12-14% N-$P_2O_5$-$K_2O$ active substance and the nitrogen is in form of $NH_4NO_3$. Before this the crop residues were smashed. After the application of the fertilizer it has been ploughed into the soil. In the spring period it was worked off and soil sterilization, while during the vegetation period pre-emergent herbicides and mechanical weed control were applied. There weren't any significant harmful pests detected.

There are irrigated and not irrigated variants in each treatment. It must be added that in 2008 the weather conditions of the area were so square, that there was no need to apply additional water. Still it is reasonable to investigate irrigated and not irrigated variants to reveal whether irrigation in the previous years has any long-term effect on production circumstances.

The three investigated hybrids were bred in Martonvásár, Hungary and belong to different FAO maturity groups, so that we can reveal differences in the reaction of hybrids in function of vegetation period. One was an early hybrid called Mv 251. It has outstanding productivity and yield safety for its short vegetation period (FAO 280) and its quick drying capacity. The other is the middle ripening (FAO 420) Mv Koppány that is also characterised by good productivity and for its steadiness by excellent yield safety. The third hybrid has the longest vegetation period: it is the Mv 500 (FAO 510). Its yield is predicting to be the highest but risks (e.g. unfavourable weather) of production endanger the yield the longest time.

The maize was sown in the last week of April 2008 and all hybrids were harvested (due to technical reasons) in the same time, in the middle of October.

We studied the yield, quality parameters and element-content of whole plants, so that we could reveal effects of each production factor and interactions between them. We took plant samples from each treatment combination seven times in the vegetation period, first in a 3-5 leaves state and last before harvesting. We measured the biomass and the dry matter as well; beside this we measured the element content of total plants with AAS method.

Soil samples were also taken in the vegetation period, of which the magnesium content and the pH in a 0.01 M $dm^{-3}$ $CaCl_2$-solution were measured. We have chosen this extractant, because it is more characteristic to the nutrient uptake circumstances than the common used and stronger ammonium lactate – acetic acid (AL). We compared the data of the soil samples taken during the vegetation period with the plant measurement data in this paper.

After all, we calculated the by the plants extracted calcium and magnesium amount per each sampling period and cumulative as well. Using the statistical method of Sváb (1981) and Tolner et al. (2008) we tried to find out and confirm, whether these are any relationship between the in the experiment investigated production factors and the soil pH, just as the calcium, resp. magnesium uptake (total incorporated and per sampling period accumulated amount) of maize plants.

**RESULTS AND DISCUSSION**

As our results of the statistical analysis show, the soil pH was affected by the irrigation and the nutrient supply levels at P=0.1% significance level. The soil pH data are shown in *Table 2.*, while the results of the statistical analysis in *Table 3.*

*Table 2.*

The soil pH measured in 0.01 M $CaCl_2$-extract (2008)

| | | Hybrid | | | |
|---|---|---|---|---|---|
| **Treatment** | **Irrigation** | **Mv 251** | **Mv Koppány** | **Mv 500** | ***Average*** |
| | | | | | |
| **Control** | irrigated | 6.60 | 6.63 | 6.61 | *6.61* |
| | not irrigated | 6.53 | 6.53 | 6.55 | *6.54* |
| | *Average* | *6.56* | *6.58* | *6.58* | *6.57* |
| | | | | | |
| **$N_{30}P_{23}K_{27}$** | irrigated | 6.46 | 6.50 | 6.48 | *6.48* |
| | not irrigated | 6.54 | 6.46 | 6.41 | *6.47* |
| | *Average* | *6.50* | *6.48* | *6.45* | *6.48* |
| | | | | | |
| **$N_{60}P_{46}K_{54}$** | irrigated | 6.49 | 6.61 | 6.49 | *6.53* |
| | not irrigated | 6.39 | 6.43 | 6.23 | *6.35* |
| | *Average* | *6.44* | *6.52* | *6.36* | *6.44* |
| | | | | | |
| **$N_{90}P_{69}K_{81}$** | irrigated | 6.54 | 6.55 | 6.51 | *6.53* |
| | not irrigated | 6.44 | 6.38 | 6.28 | *6.37* |
| | *Average* | *6.49* | *6.46* | *6.39* | *6.45* |
| | | | | | |
| **$N_{120}P_{92}K_{108}$** | irrigated | 6.38 | 6.31 | 6.37 | *6.35* |
| | not irrigated | 6.33 | 6.25 | 6.09 | *6.22* |
| | *Average* | *6.36* | *6.28* | *6.23* | *6.29* |
| | | | | | |
| **$N_{150}P_{115}K_{135}$** | irrigated | 6.33 | 6.24 | 6.28 | *6.28* |
| | not irrigated | 6.33 | 6.23 | 6.03 | *6.20* |
| | *Average* | *6.33* | *6.24* | *6.15* | *6.24* |

*Table 3.*

Table of variance regarding the effect of production factors on the soil pH

| **Factor** | **SS** | **DF** | **MS** | **F-rate** | **$LSD_{5\%}$** | **Significance** |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Irrigation (A)** | 0.41 | 1 | 0.41 | 29.64 | 0.17 | *** |
| **Nutrient-supply (B)** | 1.84 | 5 | 0.37 | 26.25 | 0.04 | *** |

As the data show, there could a significant difference be revealed between irrigated and not irrigated plots at all nutrient levels (except the $N_{60}P_{46}K_{54}$) just like a tendency that parallel to the growing nutrient dosages the 0.01 M $CaCl_2$-pH is decreasing. It can be explained by the soil acidity caused by fertilizers.

Regarding the Ca-concentration of plants it can be stated, that the highest values were measured at the beginning of the vegetation period. Then another peak in the concentration curve can be observed – in most cases – during the earing period, whereas the nutrient uptake of plants is intensive (*Figure 1*).

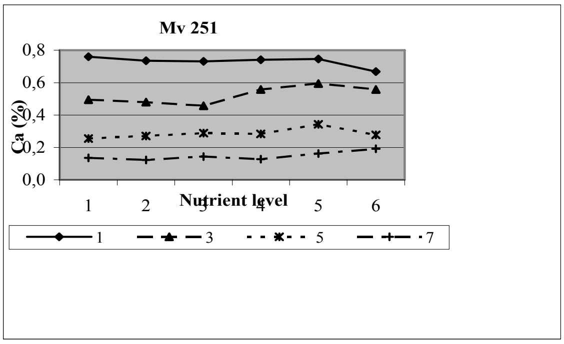


Fig. 1.: Ca-content (%) of maize hybrid Mv 251 by increasing nutrient levels and different sampling times ($1^{st}$, $3^{rd}$, $5^{th}$ and $7^{th}$)

As the results of the 3-way ANOVA show, the calcium-content (%) of plants was determined by different production factors in each sampling time. At the beginning of the vegetation period all three factors had a significant influence on the Ca-content of whole plants (irrigation at P = 10%; nutrient-supply at P = 0.1% and hybrid at P = 1.0% level). At this time the interaction between irrigation a nutrient supply level, resp. irrigation and hybrids was also significant, that means different nutrient dosages resp. hybrids had different Ca-content in function of irrigation. This fact lets us conclude, that there should be a long-time effect of irrigation on the nutrient-content of soils and the uptake of plants. Still, the results of the soil measurements should be connected to the investigation, which comes in the future (in the lack of time). We observed a difference between irrigated and not irrigated treatments only in case of the hybrid Mv 500. At the beginning of the vegetation period the Ca-content of plants dry matter was between 0.48 and 0.93%. The hybrid Mv Koppány had the smallest Ca-content (in average 0.64%), while there was no difference between the two other hybrids (0.73% resp. 0.74%). Later, in the third sampling (intensive nutrient-uptake period) nutrient-supply levels and hybrids had significant effect on the Ca-content of plants (both at P = 1.0%). At this time also Mv Koppány had the smallest Ca-content (in average 0.50%), while Mv 251 had 0.52% and Mv 500 0.58% Ca-content. At the end of the vegetation period we couldn’t reveal any significant effect of the production factors. Still a decreasing tendency of the Ca-content could be observed throughout the vegetation period.

Regarding the soil pH data it can be stated, that no consequent relationship between it and the calcium-concentration of plants could be revealed. Only in the $5^{th}$ and $7^{th}$ sampling periods there was a weak, while in the 2nd and 4th there was a medium correlation observed.

Analysing the correlation between soil pH and the in each sampling period by the plants extracted Ca-amount (kg $ha^{-1}$) we found a weak correlation in the first four sampling period, but after than no relationship.

In case of the by the plants extracted Ca-amount (kg $ha^{-1}$) a decrease at the end of the vegetation period can be observed, as shown on *Figure 2.* It can be explained by the fact, that plants are able to pump already taken up elements to the soil together with water in case of high drought.

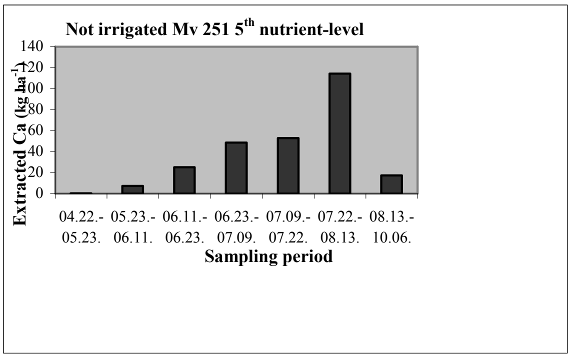


Fig. 2.: By the plants extracted Ca-amount (kg $ha^{-1}$) in case of the hybrid Mv 251, 5th nutrient level

Regarding the total extracted Ca-amount throughout the whole vegetation period, none of the three production factors had any significant effect on it. This statement is also true in case of the average extracted amounts.

Considering the between each sampling period extracted Ca-amounts we can state, that until the earing (first four sampling periods) nutrient supply affected them significantly. The highest values were observed in the treatments with the fourth nutrient level ($N_{120}$:$P_{92}$:$K_{108}$). But in case of the highest nutrient level a fall back was found. Benchmarking to the control treatment, there was only a difference between it and the 4th nutrient level.

If we have a look at the **magnesium** concentrations of plants, it comes clear, that at the beginning of the vegetation period the magnesia concentration is the highest. Later, as the plant biomass grows, its value is getting lower. It has also to be noted that in the sixth sampling period the concentration increases again, that is due to the beginning of the drying of plants (*Figure 3*).

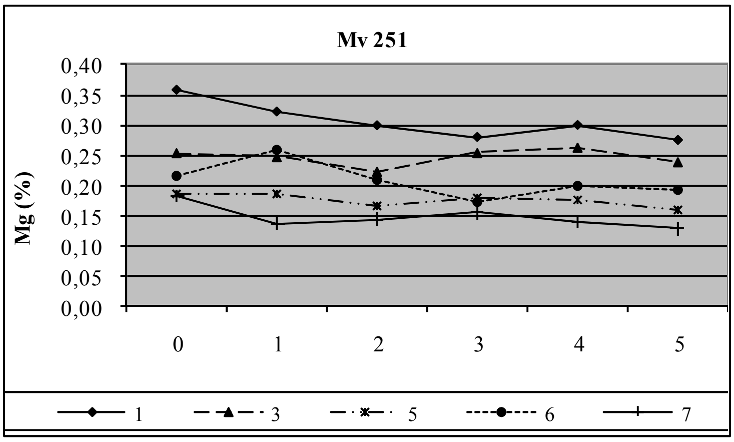


Fig. 3.: Magnesium content (%) of maize hybrid Mv 251 in five different times during the vegetation period, in function of increasing nutrient dosages

We have as well compared the soil pH-values with the magnesia concentrations of plants. We could only reveal a weak correlation in the second, fourth and in the last two sampling times.

In case of the between sampling times in the plant incorporated magnesium amount, there could a weak correlation be revealed in the first two and in the fifth sampling period, and a middle one in the third, as well.

As it becomes clear from the results of the 3-way ANOVA, at the beginning of the vegetation period all three production factors had an effect on the magnesium content of maize. The effect of nutrient supply was significant at P = 0.1%. The highest magnesium contents have been measured in the control treatment, than parallel to the first three nutrient supply levels it showed a decreasing tendency. However, we have observed in case of higher nutrient supply levels an increment of magnesium content. It is possibly due to the synergetic interaction between nitrogen and magnesia. It means, that higher N-dosages had an increasing effect on the magnesium uptake. We also concluded, that the longer the vegetation period of a hybrid is, the higher Mg-content can at the beginning of the vegetation period be measured. Still, in the intensive growing period and before harvesting had Mv 251 the highest Mg-content, while this value in case of the other two hybrids was almost similar.

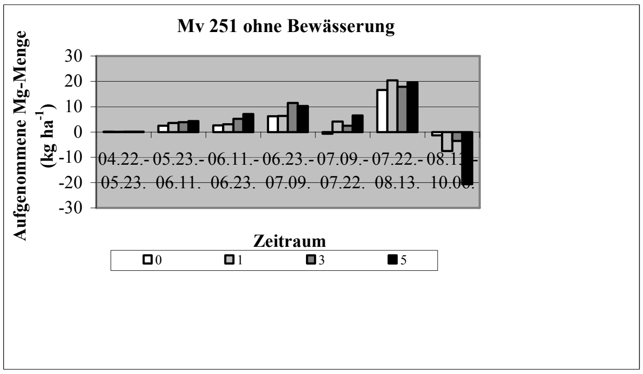


Fig. 4.: The uptaken magnesium amount (kg $ha^{-1}$) by hybrid Mv 251 (treatment without irrigation) in different sampling times during the vegetation period, in function of increasing nutrient levels

Concerning the between sampling times by plants extracted magnesium amount (kg $ha^{-1}$), it can be stated, that it was affected mainly by the maize hybrid. It means that hybrids with different long vegetation period have different nutrient uptake dynamics. Mv 251 finishes ist ripening period earlier, than the other two hybrids and begins to pump magnesium back too the soil (*Figure 4.*) at the end of the vegetation period. The uptaken Mg-amount of Mv Koppány stays the same, while Mv 500 still takes up a small amount during this period.

The total uptaken magnesium amount was also influenced mainly by the maize hybrids. Hybrids with shorter or middle long vegetation period have extracted almost the same amount of Mg from the soil, while Mv 500 – with the longest vegetation period – needed significantly more Mg for its larger biomass and yield. However, the total uptaken Mg-amount was also influenced by the nutrient supply. In the control treatment its value was of course the smallest, but by the application of mineral fertilizers its value was significantly higher.

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