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Effects of fertilizer application to sweet corn (*Zea mays.*) grown on sandy soil

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Abstract: *In our experiment we tried to find out what kind of eventual changes in the environment and in plant chemical composition occurred in response to different fertilizer treatments applied to sweet corn (Zea mays convar. saccharata) grown on sandy soil with low humus content. The ploughed layer contained <1%* $CaCO_3$ *and around 1% humus. The soil was very well supplied with P, well supplied with K, Mg, Mn and Cu, and weakly supplied with N and Ca. The treatments were planned in accordance with the recommendations, with a planned unhusked ear yield of 16 tons per hectare, of the new environmental friendly advisory system recently elaborated for field vegetable crops in Hungary. The treatments applied included: G1 (blank control)* $_{N0P0K0}$, *G2* $_{N222.5\ P22.2\ K143}$, *G3* $_{N445\ P22.5\ K143}$, *G4* $_{N222.5\ P22.5\ K143}$, *G5* $_{N222.5\ P22.5\ K286}$, *G6* $_{N222.5\ P22.5\ K143}$*+Mg* $_{1.52}$. *According to our findings, of the composition parameters of the grains of the treatments with no fertilizer application, the invert and reducing sugar contents (4.42%, respectively 2.59% relative to fresh weight* $^{-1}$*) in grains were the highest among the treatments. The same conclusion was drawn on the K 120.2, Mg 13.3, Fe 0.24, Cu 0.66 mg 100 g* $^{-1}$ *grain dry weight levels among minerals. In the case of the basic treatment (G2) recommended by the advisory system we obtained favourable results for the measured parameters, including yields. Invert and reducing sugar contents were (3.26% respectively 1.97% relative to fresh weight* $^{-1}$*), and mineral contents K 101.9; Mg 11.8; Fe 0.21; Cu 0.56 mg 100 g* $^{-1}$ *dry weight. In the grains, no translocation of toxic elements was observed in response to the direct or indirect effect of the treatments.*

Key words: *Sweet corn, Sandy soil, Mineral content, Reducing sugar content, Environmental harms*
PDF of full length paper is available online

Introduction

Considering its importance, Hungary can be said to be the leading sweet corn producing country in the European Union, besides France. In 2006 the growing area of sweet corn produced on a contractual basis, according to the communication of Fruitveb (Hungarian Fruit and Vegetable Interprofessional Organisation), was 31,000 ha, constituting 40% of the production area of field vegetable crops. From 2003 on, according to data from US Department of Agriculture, Hungary has become the 4th biggest producer in the world and the biggest exporter of processed products. Sweet corn can be brought as fresh, refrigerated or canned. According to Dewanto *et al*. (2002) the antioxidant activity will not be reduced even after canning. Sweet corn requires water and minerals to grow and to develop its organs. Nitrogen has an exceptional importance in plant life. Its deficiency or excess is more easily observable compared to any other elements. Of the individual plant organs, the fruit, in the botanical sense, is the one where the NPK nutrient levels show the lowest fluctuation. In the case of the N content the limit value is around 28%, while the highest deviation occurs in the case of the K content, being even as high as 50% (Terbe, 2004; Almodares *et al.,* 2008). Plant N content generally is found to be 15% expressed per dry matter, 1.39-1.98 N % in the grains and 0.72-1.21 N% in the stem (Fuleky, 1999). Phosphorous is an essential element for every living organism but its yield increasing effect is less spectacular compared to that of the nitrogen, as having a less strong stimulation on the growth of vegetative organs. It has a role, among other things, in the nucleic acid and membrane synthesis, in the photosynthesis, in the respiration, in the redox processes, in the activation/deactivation of enzymes, in the carbohydrate metabolism and in the N fixation (Vance *et al*., 2003). Fruit phosphorous levels are generally 0.2-0.5% of the dry matter content (Kirkby, 2007). Potassium, the cation occurring in the greatest amount in plants, plays an important role in several physiological and biochemical processes (Igras and Danyte, 2007). Along with nitrogen, it is the mineral which is absorbed in the greatest quantity (Marschner, 1995). It improves considerably the efficiency of water utilisation and the disease resistance of plants. It activates more than 60 enzyme reactions. The importance of magnesium is revealed in the protein and photosynthesis, as well as in the enzyme reactions of starch production. Furthermore, it is required for the activity of a number of enzymes and at the same time takes part in the formation of the high energy phosphate compounds. Magnesium applied in the form of foliar fertiliser will remain in the leaves and will not move with plant sap. Sandy soils are generally poorer in magnesium. As the concentration of magnesium becomes higher the aluminium toxicity will be reduced (Debreczeni, 1999).

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The investigations concerning the role of zinc have revealed that, together with other micro nutrients (Mn, Mg and Fe), it assists and stimulates the photosynthesis and the intensity of the latter, as well as being indispensable in the activation of the enzymes of certain growth hormones. Concerning the human organism, it is the co-factor of more than 200 enzymes (Devasagayam *et al*., 2004). Its absorption can be impeded by the excessive presence of phosphorus. According to Kadar (2002), the P/Zn ratio was 150-200 in grains, in soils rich in phosphorous. Herrmann (2001) has reported the mineral composition in grains. Arun Kumar *et al*. (2007) found the grains to have a reducing sugar level of 2.3-3.2%.

The experiments of Kastori *et al*. (2007) with triticale, winter wheat, poppy, pea and corn revealed that the translocation of Ni, Cu, Zn, Mo, Sr and Ba into the grains was the lowest in the case of corn. Their assimilation into plant organs was influenced by various biotic (plant species, genotype, phenophase, plant part, transpiration *etc.*) and abiotic factors (chemical properties and concentration of the toxic materials, soil conditions *etc.*) (Kastori *et al*., 2004). In their experiments with triticale Kastori *et al*. (2006) found that the flow of Ni, Cu and Zn from vegetative parts into grains was intensive, while of Mo was average. According to the data from Kabata-Pendias and Pendias (2000) the phytotoxic doses can be 5-100 mg Cd, 30-300 mg Pb and 20-100 mg Cu kg^{-1} plant dry matter. Nemeth and Kadar (2005), on the other hand, did not find any significant translocation from soil into plant in the case of As, Hg, Ni, Cu, Pb, Ba and Sr. In his experiment Gyori (2007) found a decreasing tendency of Cu content in corn grains following of phosphorus mineral fertilisation. Some heavy metals (Cd, Cr, Ni and Zn) content, particularly the nickel reduced significantly the emergence of maize and rice seedlings (Pandey *et al*., 2008). Spinach and radish have been reported to contain high metal levels (Pandey, 2006).

In our trial we studied, if on soil used for intensive crop production, the double increasing of nutrient doses more than recommended by the new environmental friendly advisory system, it can improve yield quality and quantity of sweet corn and what kind of environmental harms could it have.

Materials and Methods

The experiment was set up in the year 2006 at the Experimental Farm of the Faculty of Horticultural Science of the Corvinus University of Budapest, located at Soroksár on an area equipped with irrigation facility. Soroksar is situated on southern part of Budapest (Capital City of Hungary) on the left side of the river Danube.

The pH was measured in 1:2.5 distillate water-soil suspension , using the BOECO BT-600 apparatus; salt content was measured with SCHOTT Lab 960 conduct meter; humus content analysis was carried out with Tyurin method and used the GBC 916 UV/VIS photometer; ammonium lactate-soluble P_2O_5 and K_2O content was determinate with method of Egner *et al.* (1960); for $CaCO_3$ content analysis was used the Scheibler method; $NH4^-$ acetate+EDTA soluble (Lakanen and Ervio, 1971) microelements (Fe, Cu, Mn and Zn), towards the K_2O and Mg content was analysed with atom adsorbed spectrophotometer GBC 902. For NO_3-N and P_2O_5 measuring was used CONTIFLO apparatus. The used test variety in our trail was Spirit.

Propagation was carried out on April 20^{th} using direct seeding at a depth of 3 cm. The treatments were carried out through the application of fertilisers. No farmyard manure was applied. Four parallel repetitions were used. A combination of ammonium nitrate (34%), super phosphate (19.5%) and KCl (60%) was used for the treatments where approximately half of the N rate (10 g m^{-2}) and the total of the P and K rates were applied as starter fertilization on 13^{th} April, while the remaining part of the N rate was applied in two parts as top dressing: at the 6 to 7 leaf stage (26^{th} May) and at tasselling (16^{th}June). The treatment G3 was an exception where the 2N fertilization, besides the aforementioned dates, was applied on two further occasions (2^{nd} and 9^{th}June). In the application of the N top dressing rates we were cautious not to apply an active ingredient dose of over 50 kg ha^{-1} in order to prevent salt damage. The foliar application of magnesium also took place at tasselling (16^{th}June). The NPK requirement according to the soil test was determined in the system using the nutrient balance approach, in accordance with the new advisory system recommended by Terbe and Csatho (2004), with a (planned) unhusked ear yield of 16 tons per hectare.

G1 = Blank control (no fertiliser applied); G2 = N-P-K (control): 222.5 kg N; 22.5 kg P_2O_5; 143 kg K_2O per hectare; G3 = 2N-P-K: 445 kg N; 22.5 kg P_2O_5; 143 kg K_2O per hectare; G4 = N-2P-K: 222.5 kg N; 45 kg P_2O_5; 143 kg K_2O per hectare; G5 = N-P-2K: 222.5 kg N; 22.5 kg P_2O_5; 286 kg K_2O per hectare; G6= N-P-K (control) + MgO 1.52 kg.

After harvesting 20 ears were randomly selected from each treatment and the following measurements were carried out:

Average unhusked ear yield (kg ha^{-1}), Dry matter content (%): according to the standard MSZ (Hungarian standard) 2429-1980. Sugers were determined according to Luff-Schoorl method (1929).

Furthermore, investigations were made into grain mineral contents (K, Ca, Mg, Fe, P, Cu, Mn and Zn) as well as into those of toxic elements (As, Cd, Cr, Ni, Pb and Sr) using the apparatus ICP-OES Thermo Jarrell Ash.

The statistical analysis was carried out by using the programme MiniStat 3.3 with the help of which we performed one-way comparison of repeated measures. The differences between the homogenity of variances were tested with Levene test (Balog and Marko*,* 2007; Balog *et al.,* 2008a). $p<0.01$ confidence limits are considered as statistically significant differences (Balog *et al.,* 2008b). When the standard deviations were identical, the mean values were compared by pairs using the Tukey-Kramer test, while in the case of the non identical standard deviations the means were compared using the Games-Howell test (Vargha, 2007).

Results and Discussion

According to Jakab and Krezsek (2008) the pH value was slightly alcaline, the NO_3 content was low (0.92 ppm) in case of G1 treatment and very high (71.1 ppm) in case of G3 (Table - 1). The Mn content, >40 ppm, was considered also very high. The very high value of NO_3 presents a real threat on sandy soil with low humus content, it can leach in underground water in case of heavy rainfalls (Table 1). As result of intensive fertilisation compared to Kadar and Rekasi (2008) we found similarly increasing of Mg content and same tendency in Cu and Zn content accumulation. Kadar and Ragalyi (2008) consider fertile plots when 120-150 ppm range ammonium lactate-soluble P_2O_5 and K_2O in ploughed layer is supplied of about 150 kg N yearly.

Based on the figure 1 it can be seen that highest yield was achieved in response to the NPK basic treatment (G2), the yield being from 440 to 2020 kg higher compared to the other treatments. The lowest unhusked ear yield was measured in the case of the treatment G1 which was significantly inferior ($p<0.01$) to the average of the other treatments. In our trial we did not observe reducing of yield quantity through plants missing as result of reduced germination (Pandey *et al.,* 2008).

Table - 1: Result of soil macro and microemeloent content of collected plots to treatments, after harvesting

Parameters	Treatments					
	G1	G2	G3	G4	G5	G6
pH	8.3	8.1	7.5	7.9	8	7.9
Salt (%)	0.020	0.024	0.052	0.018	0.022	0.017
Humus (%)	0.96	0.94	1.02	0.91	1.13	0.48
K_A	< 30	<30	<30	<30	<30	<30
NO_3-N (ppm)	0.919	20.045	71.15	18.7	10.135	10.5
P_2O_5 (ppm)	553	611	381	486	478	497
K_2O (ppm)	279	284	360	367	592	360
Ca (%)	0.9	1	0.7	0.7	0.4	0.5
Mg (ppm)	87.95	72.75	76.95	83.15	81.3	88.9
Fe (ppm)	60.3	57.5	59.2	71.8	91.1	82.7
Mn (ppm)	103	103	124	141	201	184
Zn (ppm)	5.01	6.08	6.08	5.74	7.67	6.69
Cu (ppm)	4.1	4.6	4.7	5.3	6.5	5.9
$CaCO_3$ (%)	<1	<1	<1	<1	<1	<1

Grain dry matter content (Fig. 2), which is an indicator of the stage of ripeness, was the lowest in the case of the blank control (22.6%), the highest in the G3 treatment (26.8%) while intermediate values were registered for the other three treatments (24.3-24.8%). According to the results, the raised nitrogen level resulted in a slightly earlier ripening. The shortage of nutrients (blank control) had a ripening retarding effect. On the other hand, no statistically demonstrable difference was found between the treatments.

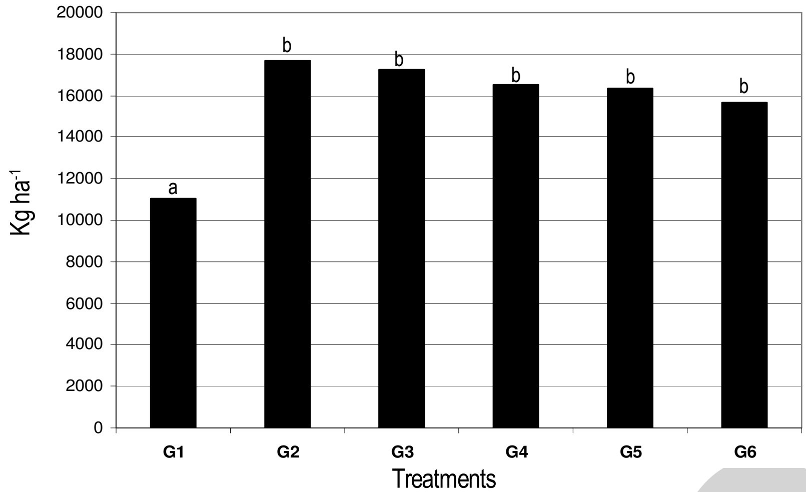
During the course of our measurements, relative to the sugar contents (invert and reducing), our findings suggested (Fig. 3) that the treatment G1 (no fertilizer application) had a significantly higher invert sugar content compared to the other treatments which was also statistically demonstrable ($p<0.01$). Probably, due to the lower amount of available nutrients, the accumulation of the carbohydrates serving as a nutrient reserve started earlier and at a faster rate. Compared to the data by Herrmann (2001), according to our findings, the concentration of the reducing sugars was superior to 1 g. Relative to the reducing sugar content, such data as published by Arun Kumar *et al*. (2007) (2.3-3.2%) were encountered only in the case of the treatment G1. In the case of the treatments with fertilizer applications the highest sugar content was registered in the grains of the treatment G2 recommended by the new environmentally friendly advisory system.

Relative to the accumulation of Mg, K and Ca the highest average level was registered for the treatment without fertilizer G1 (Table 2). The fluctuations in potassium levels (even as high as 50%) seems to confirm the observations of Terbe (2004). The samples of the treatment G 6 with supplementary foliar application of Mg had higher Mg, K and Ca contents compared to the other treatments (except for the treatment G1), which suggests that the foliar application of Mg had favourable effect. At the same time the highest concentration of P was measured in the grains of G 3 treatment. Studying the mineral content of the treatment G 2 we found that the levels of the elements analysed did not differ significantly compared to the other treatments.

The highest Fe and Cu contents of grains were measured in grains of G1 treatment and the highest Zn content in case of G3 treatment. No significant difference of microelement content in grains

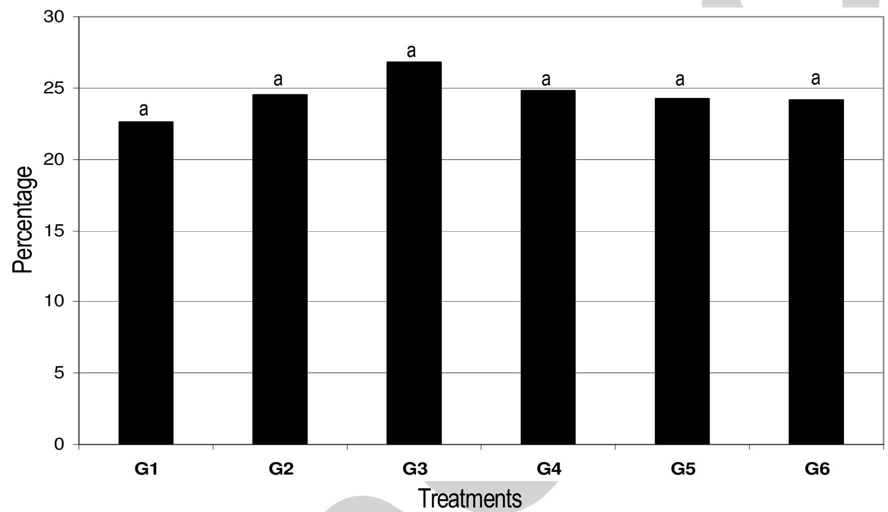
Table - 2: Average mineral content obtained in mg related to 100 g dry weight of grain samples belonged to each treatment (are represented also the maximum and minimum deviation of replications from the average)

Mineral Content	Treatments					
	G 1	G 2	G 3	G 4	G 5	G 6
Mg	13.3±1.5	11.8±0.8	12.9±0.4	11.8±0.3	11.8±0.1	13.1±0.1
Ca	8.1±0.1	8.4±0.4	7.8±0.2	6.8±0.1	6.76±0.1	7.3±0.4
K	120.2±8.7	101.9±1	105.7±4.3	108.1±7.5	107.8±2.5	114.7±1.3
P	34.8±0.3	32.1±0.4	35.3±0.1	33.5±0.1	33.6±0.3	33.6±0.3
Fe	0.24±0.04	0.21±0.06	0.23±0.04	0.22±0.09	0.21±0.07	0.23±0.02
Mn	0.12±0.01	0.11±0.02	0.11±0.01	0.12±0.03	0.11±0.01	0.13±0.04
Zn	0.28±0.01	0.25±0.01	0.29±0.04	0.26±0.01	0.26±0.04	0.26±0.01
Cu	0.665±0.06	0.557±0.02	0.482±0.03	0.513±0.01	0.456±0.02	0.588±0.01



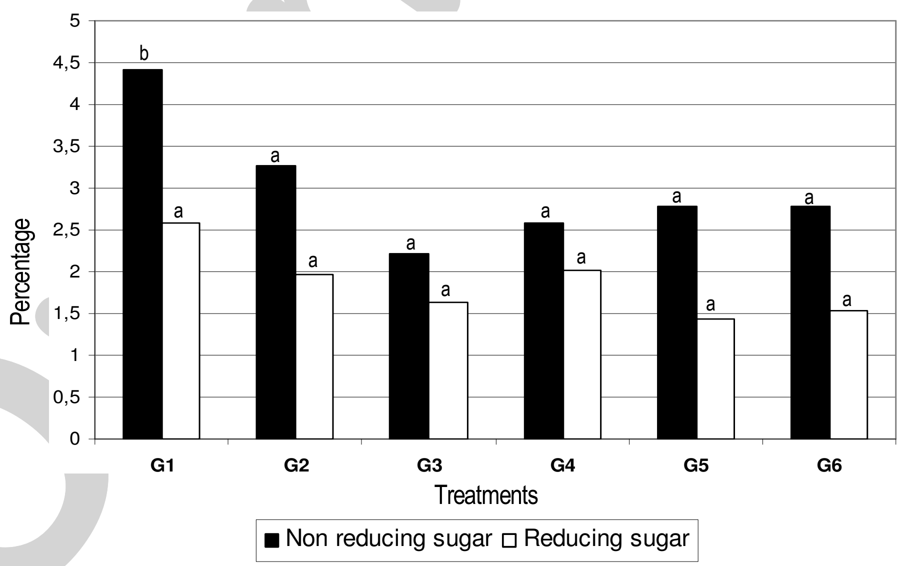
Sd = 99%
F (6.21) = 8068

Fig. 1: Results of total ear yield calculated to 1 hectare



Sd = 99%
F (6.21) = 0.865

Fig. 2: Resulta of dry matter content of grains relative to 100 g fresh grain weight



Sd = 99%
F (6.27) = 5.294

Fig. 3: Results of non reductive and reductive sugar content of grains relative to 100 g fresh grain weight

Table - 3: Toxic element content obtained from dry grain samples (µg g^{-1} dry wt.)

	G1	G2	G3	G4	G5	G6
As	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5
Cd	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Cr	< 0.5	< 0.5	< 0.5	0.6936	< 0.5	< 0.5
Ni	0.5646	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Pb	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5
Sr	2.854	2.634	2.344	2.114	1.954	2.194

among the treatments. We haven't observed decreasing tendency of Cu content in grains compared to Gyori (2007).

According to our experiences, the elements measured by us which are harmful to human health, did not accumulate in the grains since the amounts of As,<2.5; Cd, <0.5; Cr,<0.5; Pb,<2.5 and Ni, <0.5 not counting a few exceptions (Sr, 1.95-2.85, Cr, 0.69 and Ni, 0.56 µg g^{-1} dry weight) were under the detection threshold of the instrument used.

The accumulation of the toxic elements Ni, Cu, Zn, Mo, Sr and Ba followed a similar tendency to the findings of Kastori *et al*. (2007), as their presence under the detection level seem to confirm the hypothesis that they were either absent from the soil or did not translocate into the fruit. At the same time, the observations of Nemeth and Kadar (2005), *i.e.* the slight translocation of As, Hg, Ni, Cu, Pb, Ba and Sr from the stem into the fruit coincided with our findings. Such levels of Cd, Pb and Cu as could be harmful to plants, as reported by Kabata-Pendias and Pendias (2000), and levels of Cu, Cr, Ni and Zn reported by Pandey (2006) were not encountered.

Based on the experiments carried out so far, we have arrived to the following conclusions: (1) When no fertiliser was applied low yields were achieved representing a threat to the profitability of production. (2) The NK applied in a double dose produced an increase in the salt content of the soil but they did not increase significantly the yields or the dry matter level. (3) With the double dose application of active ingredients the uptake of micronutrients was also increased, because their levels were diminished in the soil samples collected after harvest. (4) The nutrient applications with different doses resulted in poorer yield quality, but the smallest decrease was caused by the treatment G2 which was carried out in the spirit of the new environmental friendly advisory system. No signs of damage to the environment were seen in any of the treatments.

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