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Effect of different starter and foliar fertiliser rates on some compositional parameters of sweet corn (*Zea mays* convar. *saccharata* Koern.)

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Summary: In recent years consumers tend to pay ever greater attention to food ingredients looking for foods with favourable compositional characteristics. Researches nowadays aim to find out what role the different vegetable species play in protection of the human organism. Consumption of vegetables and fruits more times a day plays an important role in this process. The valuable chemical components in plants can eventually be influenced, besides, by environmental characteristics, also by the elements of the production technology applied. Our work aimed to find out what eventual changes occur in the composition parameters of sweet corn (*Zea mays convar saccharata Koern.*) receiving different NPK fertilizations and top dressed with foliar application of Zn and Mg, destined chiefly for fresh consumption, in response to the treatments mentioned above. The fertiliser rates were compared with the help of the variety Spirit (normal sweet, very early ripening).

Key words: sweet corn, dry matter content, mineral content, sugar content

Introduction

Considering its importance, Hungary can be said to be the leading sweet corn producing country of the European Union. In 2006 the growing area of sweet corn produced on a contractual basis was 31,000 ha constituting 40% of the production area of field vegetables. From 2003 on, according to data from USDA, Hungary has become the 4th biggest producer in the world and the biggest exporter of processed products.

The season of fresh consumption from the field lasts from the second half of June to the end of September. The consumption of sweet corn has come into the forefront with the progression of modern nutrition and with the changes in dietary habits.

Complex epidemiological studies have revealed that vegetable and fruit consumption can reduce the occurrence of chronic diseases, e.g. cancer (*Block* et al., 1992), heart disease and stroke (*Joshipura* et al., 1999). Based on US investigations diabetes occurring among women was indirectly proportional to vegetable and fruit consumption (*Ford & Mokhad*, 2001).

The sugar content of sweet corn can differ significantly by the type of variety (normal sweet, increased sugar content, super sweet). According to the publication of *Hermann* (2001) the amount of the reducing sugars is around 1 g and that of the sucrose is 2.16 (1.6–2.7) in 100 g fresh grains. According to the findings of *Arun Kumar* et al. (2007) the reducing sugar content of the grains harvested is 2.3–3.2%, the non reducing sugar content is 17.01–24.38% and the total sugar contents range between 21–29.6%.

The of chemical composition parameters (expressed per 100 gram fresh grains (*Biró & Lindner*, 1999)) of sweet corn are: energy 550 kJ, proteins 4.7g, lipids 1.6, carbohydrates 23.6 g, water 67.7 g, ash 0.9 g, crude fibres 1.5 g, total food fibres 8.8 g. carotenes 0.1 g, tokoferol 0.06 mg, thiamine 48 µg, riboflavin 57 µg, pantothenic acid 0.65 µg, pyridoxine 0.12 µg, biotin 2.7 µg, folic acid 26 µg, ascorbic acid 7 µg, calcium 7 µg, iron 0.6 µg, copper 0.06 µg, zinc 0.444 µg and manganese 0.13 µg.

In the case of sweet corn we have a vegetable with very high nutrient demands and at the same time it is grown on a big area (often in monoculture) therefore fertilizer application is one of the most important parts of the production technology. Of the three major nutrients, it is *nitrogen* that is considered to have the greatest importance, since it has a decisive influence on yields, but in case of applying a dose over 60–120 kg/ha (depending on the type of variety) a harmful accumulation of NO_3 can occur (*Sárvári*, 1995). 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% (*Terbe*, 2004). Phosphorous is an essential element for every living organism. It has a role 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 (*Huber*, 1985). Along with nitrogen, it is the mineral which is absorbed in the greatest quantity (*Marschner*, 1995).

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 (*Pethő*, 1993).

The investigations concerning the role of zinc have revealed that, together with other micro nutrients (Mn, Mg, 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 P. According to *Kádár* (2002), the P/Zn ratio was 150–200 in the grains in soils rich in phosphorous. According to the communication of *Herrmann* (2001) the mineral composition relative to 100 g weight was as follows: K 173±32 mg, Ca 0.9±0.4 mg, Mg 23±4.7, Fe 0.6±0.1 mg, Na 0.3 mg, Zn 0.56 mg, Cu 0.045 mg, Mn 0.16 mg, P 83 mg. One important moment of the successfully sweet corn production, is to choose the correctly ripening time. It happens when the dry material content of grains is around 30–35% (*Hodossi*, 2004).

Materials and methods

The experiment was set up in the year 2006 at the Experimental Farm of the Faculty of Horticulture of the Corvinus University of Budapest, located at Soroksár on an area equipped with irrigation facility. The test variety was the normal sweet Spirit. Propagation was carried out on Apr 20th using direct seeding at a depth of 3 cm. The applied treatments are summarized in *Table 1*.

Table 1. The applied treatments

Treatment	N	P_2O_5	K_2O	MgO	Zn
	Kg/ha	Kg/ha	Kg/ha	%	%
K1	0	0	0	0	0
K2	222,5	22,5	143	0	0
K3	445	22,5	143	0	0
K4	222,5	45	143	0	0
K5	222,5	22,5	286	0	0
Mg	222,5	22,5	143	5	0
2Mg	222,5	22,5	143	10	0
Zn	222,5	22,5	143	0	0,5
2Zn	222,5	22,5	143	0	1

The treatments were carried out through the application of fertilisers. No farmyard manure was used. A combination of ammonium nitrate (34%), super phosphate (19.5%) and potash (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 Apr 13th, while the remaining part of the N rate was applied in two parts as top dressing: at the 6 to 7 leaf stage (May 26th) and at tasselling (June 16th). The treatment number 3 was an exception where the 2N fertilization, besides the aforementioned dates, was applied on two further occasions (June 2nd and June 9th).

The foliar application of Magnesium was carried out using the product *Hydromag*, while the Zn treatments were performed with the product *Zintrac*, according to the following: Foliar application of 4 g/l Mg on 1 occasion (June 16th, 7–8 leaf stage); Foliar application of 4 g/l Mg on 2 occasions (June 16th, 7–8 leaf stage and June 30th, tasselling); Foliar application of 0.35 g/l Zn on 1 occasion (June 16th, 7–8 leaf stage); Foliar application of 0.35 g/l Zn on 2 occasions (June 16th, 7–8 leaf stage and June 30th, tasselling).

The harvest was carried out in two passes, in the course of which the ears were removed with their husks on. Then 20 ears were randomly selected from each treatment and the following measurements were carried out:

Yield per hectare (kg/ha)

Dry matter content (%): according to the standard MSZ 2429–1980.

Total sugar content (after inversion, using the titration method according to Luff-Schoorl).

Based on the measurements in the comparison of the treatments the difference between reducing and total sugar content (= compound sugars, chiefly sucrose) was also examined.

Furthermore, investigations were made into grain mineral contents (K, Ca, Mg, Fe, P, Cu, Mn, Zn) using the apparatus ICP-OES Thermo Jarrell Ash.

The statistical analysis was carried out by using the programme MiniStat 3.3 (*Vargha*, 2000).

Results

Results for yield per hectare are illustrated in *Figure 1*.

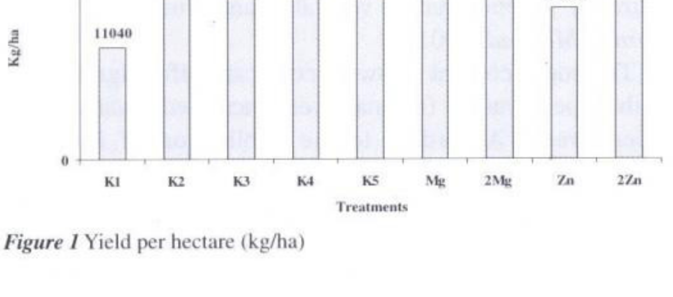

Figure 1 Yield per hectare (kg/ha)

Based on the figure it can be seen that highest yield was achieved in response to the basal NPK treatment (K2) with the foliar application of Mg, the yield being 943 kg higher compared to the other treatment K2, while the difference ranged between 1117 and 7543 kg compared to the other treatments. The lowest unhusked ear weight was measured in the case of the treatment K1 which was significantly inferior (at p<0.01 level) to the average of the other treatments.

Dry matter content is illustrated in Figure 2.

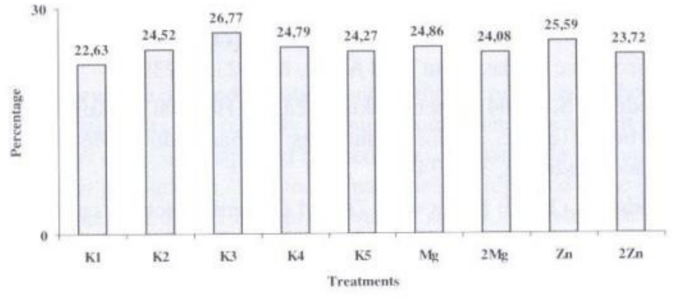

Figure 2 Grain dry matter content

The analysis of the dry matter content showed it to be the highest in the average samples of the Zn treatment. Relative to the treatments applied to the basal dressing and applied by foliar fertilisation we found that Mg had a favourable effect on the dry matter content of the grains. On the other hand, we found no statistically significant difference between the treatments.

Levels of the reducing and invert sugar contents are illustrated in Figure 3.

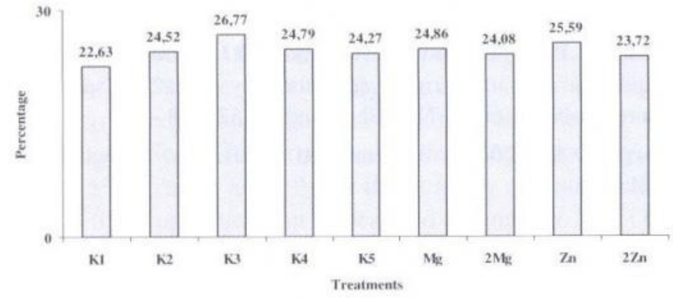

Figure 3 Reductive and invert sugar contents

During the course of our measurements, relative to the sugar contents (invert and reductive), our findings suggested that the treatment K1 (no fertilizer application) had a significantly higher invert sugar content compared to the other treatments which was also statistically demonstrable (at p<0.01 level). The foliar application of Mg and Zn on two occasions had a favourable influence on invert sugar content.

The reductive sugar content, on the other hand, was favoured by the treatments of foliar Mg application (Mg, 2Mg) and the effect of the foliar application of Zn (Zn, 2Zn) did not have a favourable effect compared to the results of the other treatments.

Mineral contents are illustrated in *Table 2* (mg/100 g)

Higher Fe, Mn and Zn contents were registered in the samples of the Mg treatments than in the case of the K1-K6 treatments.

The values of the 2Mg treatment showed substantially the same tendency as those of the Mg treatment, but were lower numerically.

The tendencies of the Fe and Zn contents of the 2 Zn treatment were similar to the samples of the Zn treatment with the difference that the Mn concentration was also higher in this case.

In the case of the Mg and Na and in particular the Ca and K contents the average samples showed a significant decrease in response to the treatments applied as top dressing compared to the K1 untreated control.

At the same time, the highest Mg and K contents were measured in the grains of the treatment K1.

The single application of Mg and Zn had a favourable effect on the Mg and p contents of the average samples, while a decrease in the Na, Ca and K content was seen compared to the K2 treatment.

In the case of the average samples that had received two foliar Mg applications the Mg and K contents were increased while the Na and Ca contents were decreased.

In the average samples that had received two foliar Zn applications higher Mg and K and lower Na and Ca levels were measured.

Discussion

The single foliar Mg application treatment had the highest yield.

The single application of Zn and Mg as top dressing had favourable influence on the dry matter contents of the grains of the respective treatments.

Table 2. Mineral element contents

	K1	K2	K3	K4	K5	Mg	2Mg	Zn	2 Zn
Mg	13,3±1,5	11,8±0,8	12,9±0,4	11,8±0,3	11,8±0,1	12	12,6±0,2	12,3±0,2	13,1±0,2
Na	3,6±0,1	3,9±0,1	4	3,6±0,1	2,9±0,1	3,2±0,1	3,3±0,1	3,5±0,1	3,3±0,4
Ca	8,1±0,1	8,4±0,4	7,8±0,2	6,8±0,1	6,76±0,1	7,4±0,1	7,3±0,1	7,1±0,1	7,4±0,4
K	120,2±8,7	101,9±1	105,7±4,3	108,1±7,5	107,8±2,5	100,9±4,9	104,6±6,8	93,8±7,6	111,1±6,5
Fe	0,24±0,04	0,21±0,06	0,23±0,04	0,22±0,09	0,21±0,07	0,24±0,06	0,24±0,08	0,25±0,02	0,27±0,02
Mn	0,12±0,01	0,11±0,02	0,11±0,01	0,12±0,03	0,11±0,01	0,14±0,02	0,13±0,09	0,11±0,01	0,13±0,01
Zn	0,28±0,01	0,25±0,01	0,29±0,04	0,26±0,01	0,26±0,04	0,32±0,01	0,33±0,02	0,33±0,01	0,34±0,01
P	34,8±0,3	32,1±0,4	35,3±0,1	33,5±0,1	33,6±0,3	34,9±0,2	34,1±0,2	32,9±0,7	36,3±0,9

The process of the accumulation of the reducing and invert sugars was most strongly favoured by the treatment K1, probably, as a result of the low nutrient level the accumulation of the carbohydrates serving as a nutrient reserve was started earlier and at a higher rate.

Compared to the data of *Hermann* (2001), according to our findings, the amount of the reducing sugars was over 1 g. The data reported by *Arun Kumar* et al. (2007) relative to the level of reducing sugars (2.3–3.2%) was encountered only in the case of the K1 and the 2 Mg treatments.

The application of zinc and magnesium as foliar fertilisers had a positive effect on the level of Fe, Mn and Zn considered as micro nutrients but playing a very important role in the ion balance of the body. The levels of Na and Ca were significantly higher than the data reported by *Hermann* (2001). On the other hand, significantly lower values were registered in the case of the other micro nutrients (Mg, K, Fe, Mn, Zn, P). The 150–200 P/Zn ratio found in the grains by *Kádár* (2002) was not achieved but was only approached.

The reason for the lower compositional values, according to our hypothesis, is that the experiments were carried out on sandy soil in order to enhance earliness and this resulted in a faster fruiting period.

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