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Effects of foliar treatments on the yield and quality of sugar beet

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1. Introduction

In Hungary, sugar production based on sugar beet started in a small factory in Ercsi at the end of the 1800s. The reason was the retalioratory embargo instituted by Napoleon (1806), preventing the import of cane sugar to Europe. Since the climate in Europe is not suitable for sugar cane production, European countries were encouraged to grow sugar beet and develop process technologies. In Hungary, the actual start of sugar beet production was in 1830.

Sugar is produced in 120 countries in the world, based on two types of raw materials: sugar beet (in almost 50 countries) and sugar cane (in approx. 100 countries). The most important sugar producers are China, Brasil, India and the EU.

Today, the sugar consumption of the world is 146 million tons, of which 75% -80% is made from cane sugar and the rest is from sugar beet, the cultivation area of the latter is 6 million hectares. The biggest cultivation areas are in Europe and in North America. By 2015 the consumption is expected to reach 175 million tons, and the solution of this high demand will be sugar cane for the effectiveness of its cultivation and production.

Another tendency is the growing market share of isoglucose and other artificial sweeteners (intensive sweeteners: sacharin, ciclamat, aspartame). In some countries, for e.g. in the USA isosugar made from corn diverted special industries (soft drinks) from sugar beet and cane sugar.

In the last decade in the sugar beet industry both production and processing has undergone significant changes not only in the world, but in Hungary. In Hungary, sugar production aims at supplying the Hungarian market with good quality sugar. It is well described by the 400 thousand tons production quota of the EU, which is suitable to satisfy the national demand.

It is essential to mention the recent changes and their background in the sugar industy. In July 1 2006, the European Union introduced a new regulation on the sugar market (the regulation in the EU has been on since 1968, based on practically unchanged principles). This regulation has fundamentally changed the operation of the sugar market of both the world market and the EU. Therefore, it states new challenges towards Hungary as well, as our sugar factories are owned by foreign concerns.

The objective of the regulation was to channel the huge sugar surplus of the European Union and by decreasing the price of sugar from sugar beet and intervention sugar to enhance the competitiveness of the industry.

The effect of the reform has manifested in Hungary as well, as in October 2006 the sugar factory of the Eastern Sugar in Kaba was closed. Thus, only 4 factories remained in the

Hungarian market. In November 2007 the Szolnok factory was closed as well. Another perceptible effect of the sugar market regulation was the significant decrease of the sugar quota.

Accordingly, the objective for our sugar beet production is given, i. e. increasing the sugar yield per hectare, ensuring the stability, approaching the European standard and last but not least improving the quality. The quality of the yield primarily depends on inner factors, which is the complexity of the genetics of a given plant culture (for e.g. the protein content of the grain, the sugar content of the sugar beet). However to a certain extent, some external factors can also modify it, such as agrotechnical procedures, especially nutrient supply.

My scholarship was provided for 2 and half years by the factory of the Eastern Sugar in Kaba. Based on our results their objective was by reaching the appropriate product yield and appropriate sugar yield per hectare, to ensure uniform and good quality raw material, and to use the results in practice. We did not try to change an already working cultivation technology, we only tried to complement it. Accordingly, the usual agrotechnical practices have been supplemented by foliar treatment.

2. Material and methods

2.1. Introducing the experiments

The experiments have been conducted in Hajdúböszörmény (N 47˚41' E 21˚30') on two cultivation sites of the Béke Agricultural Cooperation and Hajdúböszörmény Agricultural Plc. in four replicates. The experiment has been conducted in two years, in 2005 and in 2006. The experiments were set up with the assistance of Dr. Péter Pepó, Head of the Institute of Crop Science. 6 treatments have been applied on the experimental sites (including the control plot i.e. the plot treated according to the technology of the farm). The total number of the plots was 24 in both research years. The size of the plots was 24 m × 300 m in the first year, in 2006 slightly smaller plots were used - 12 m × 300 m for Béke Agricultural Cooperative and 16 m × 150 m for Hajdúböszörményi Agricultural Plc. The size of the plots has been reduced because of soil inhomogenities in the second year. Tables 1, 2 and 3 shows the treatments, their application dates and the amount of nutrients.

Table 1.: Treatments and application dates in 2005

Treatments	Dose	Date (2005)		
		31.05. and 03.06	21.06. and 27.06.	01.08. and 31.08.
1. Control		-	-	-
2. Biomit plussz	4 l ha^{-1}	+	+	+
3.Fitohorm Euro-Öko Gyökérgumós	4 l ha^{-1}	-	+	+
4. Cosavet DF	5 kg ha^{-1}	-	+	-
5. KelCare Cu	0,5 kg ha^{-1}	-	+	-
6. Cosavet DF+KelCare Cu	5 kg ha^{-1}+ 0,5 kg ha^{-1}	-	+	-

Table 2: Treatments and application dates in 2006

Treatments	Dose	Date (2006)		
		25. 05.	05.07.	16.08. and 21.08.
1. Control		-	-	-
2. Biomit plussz	4 l ha^{-1}	+	+	+
3.Fitohorm Euro-Öko Gyökérgumós	4 l ha^{-1}	-	+	+
4. Cosavet DF	5 kg ha^{-1}	-	+	-
5. KelCare Cu	0,5 kg ha^{-1}	-	+	-
6. Cosavet DF+KelCare Cu	5 kg ha^{-1} + 0,5 kg ha^{-1}	-	+	-

Table 3: Amount of nutrients in the treatments

Treatments	Nutrients										
	N	**P_2O_5**	**K_2O**	**B**	**Ca**	**Cu**	**Fe**	**Mg**	**Mn**	**Mo**	**S**	**Zn**
	kg ha^{-1}			(g ha^{-1})								
Control (2005) (Béke A. Coop Hb Agr. Plc.)	83 51	30 40	90 98									
Control (2005) (Béke A. Coop Hb Agr. Plc.)	83 51	30 40	90 98									
Biomit Plussz				3,2	450	51,2	44,8	320	25,6	1,28		44,8
Fitohorm EÖGY	0,144		0,96	96				144	24		288	
Cosavet DF											4000	
KelCare Cu						70						
Cosavet DF + KelCare Cu						70					4000	

Spraying machine was used to apply the treatments; the amount of water was 200 l ha^{-1}.

The soil of the experimental site is chernozem, characterized by excellent condition and 70-90 cm deep fertile layer. The nutrient status (both macro- and microelements) and water supply of the soils was good, the Nitrogen, Potassium and Phosphorus supply were sufficient – good. The soil of both sites is suitable for sugar beet production.

2. 2. The climate of the research years

In 2005, the average monthly temperatures have been almost identical to the 30 year average in the growing season of sugar beet (September-October). Considering the temperature of the growing season, in April and July the temperature was under average. The seven-day long low temperature (around zero) in the first ten days of April was unfavourable for the sowing and early growing of sugar beet. The average temperature was slightly higher than the 30 year average in May and June, while it showed significant variances in August, September and October - 2,4; 1,5 and 1,8 ºC – however, the precipitation was sufficient.

Examining the average monthly temperature in 2006 we find that the temperatures of March, May and August are lower than the 30 year average, at the same time, in the remaining months of the growing season the avereage temperature exceeded it. It was favourable that the avereage temperature in April was 1 ºC higher than the 30 year average and it was beneficial for the sowing of sugar beet. In July and September the avereage temperature was above the 30 year average, the variation in these months was 2.2 and 1.45 ºC, accompanied by lower-than-avereage precipitation. This climate was in no way beneficial, considering the avoidance of leaf change.

2. 3. The agrotechnical processes in the examined firms

In the research plots on both experimental sites, the usual agrotechnical processes like soil cultivation, sowing, nutrient supply and plant protection was done according to the practices. Accordingly, on the experimental site of Béke Agricultural Cooperative the forecrop was winter wheat in both years, on the experimental site of Hajdúböszörményi Agricultural Plc. it was winter wheat in 2005 and sweetcorn in 2006. The basic autumn cultivation was ploughing in both sites, which was finished in autumn. The first cultivation process in spring was done by combinator at Béke Agricultural Cooperative at the end of March, and by combinator at Hajdúböszörményi Agricultural Plc. in the middle-end of March. The seedbed was done directly before the sowing, at the very beginning of April.

The nutrient supply was provided by 300 kg ha^{-1} Kemira Beta Power (5:10:30 – N, P, K) at Béke Agricultural Cooperative in both research year, previously in August 2004 40 t ha^{-1} farmyard manure was given. In 2005 and 2006 the nutrient supply was provided in the form of Nitrogen (200 kg ha^{-1} NH_4NO_3) i.e. 68 kg ha^{-1} Nitrogen active agent, right before making the seedbed.

At Hajdúböszörményi Agricultural Plc., previous to the growing season in autumn 400 kg ha^{-1} complex fertilizer (0:10:24,5 – Nitrogen, Phosphorus, Potassium) was provided in both years, which was complemented by 150 kg ha^{-1} NH_4NO_3 (51 kg ha^{-1} N active agent) in the spring.

The sowing time was 2 April 2005 (Béke Agricultural Cooperative) and 7-8 April (Hajdúböszörményi Agricultural Plc.). We used Picasso and Liana varieties. In both experimental sites the amount of the coated seed was 1.4 Unit. In 2006, Baltika was grown at both experimental sites, the sowing time was 25 April, the amount of the coated seed was 1.2 Unit.

All three varieties are tolerant to beet necrotic yellow vein virus and resistent to Cercospora.

Simultaneously with sowing, Counter 5G soil disinfectant was provided in both years (9 kg ha^{-1} and 10 kg ha^{-1} at the Béke Agricultural Cooperation, while at the other experimental site, 10 kg ha^{-1} and 12 kg ha^{-1} in 2005 and 2006, respectively). Pre-emergent weed control was done at the Béke Agricultural Cooperation in 2005 and at the Hajdúböszörmény Agricultural Plc. in 2006 (Dual Gold - 1,6 l ha^{-1} and a Pyramin Turbo - 4,0 l ha^{-1}). Postemergent weed control (Betanal Expert – 1,2 l ha^{-1}, Goltix – 1,5 kg ha^{-1}) was done at both sites in both years. The soil was cultivated and manually hoed, and insecticides were applied at both experimental sites (Sumi-alfa - 0,3 l ha^{-1} and Thiodan 35 EC - 1,5 l ha^{-1}).

In our field experiment, these usual practices have been complemented by foliar treatment. As regards the treatments, two types of foliar treatments have been provided, both containing microelements (Biomit plussz, Fitohorm Euro Öko Gyökérgumós). Furthermore, Sulphur as the fourth macroelement (Cosavet DF), and Copper (KelCare Cu) as an important microelement was provided, and the joint effect of these elements has been analysed.

2. 4. Description of the foliar fertilizers used

With foliar treatments 2 and 3 (Biomit plussz and Fitohorm Euro Öko Gyökérgumós, in Table 1 and 2) our aim was to, besides the macro element supply, ensure the microelement requirements of sugarbeet. The reason is that microelement deficiency is often not well-marked but their supplement is essential for good quality.

The composition of the product used in the 2nd treatment was the following: Ca 7%, Mg 5%, Fe 0,7%, Mn 0,4%, Mo 0,02%, B 0,05%, Zn 0,7%, Cu 0,8%, as well as more than 60 plant extract. Plant extracts are on the one hand enhancing the absorption of nutrients; on the other hand they function as special insecticides. Their scent affrays some pests and makes plants more resistant to fungal diseases. Used 2-3 times a week in 1-2 % concentration in the growing season improves the efficiency of plant protection techniques. Forming a thin layer on the surface of the plant it provides physical protection as well.

The composition of the compound used in the 3rd treatment was the following: 3% N, 2% K_2O, 3% Mg, 0,5% Mn, 2% B and 6% S.

The active agent of the product used in the 4th treatment (Cosavet DF) is Sulphur, which given 4-5 kg ha^{-1} is an effective method of Sulphur supplement. So far, Sulphur was only considered as one of the elements most responsible for environmental pollution; for today, its importance is recognized in agricultural production as well. Sulphur, being an important component of mineral nutrition, is instrumental in photosinthesis, respiration, Nitrogen and carbohidrate metabolism and in the forming of chlorofill, carotenoids, several vitamines and enzimes. It is also instrumental in the prevention and mitigation of stress. Sulphur deficiency symptoms are similar to that of Nitrogen deficiency, i. e. clorosys.

During the 5th treatment (KelCare Cu), a foliar fertilizer to supply micro elements was provided, the active agent was 14 m/m% Cu EDTA Copper-chelate. Literature claims that while Sulphur and boron supplement are the most important elements for the shooting beet, as the growing season elapses, besides Sulphur and Potassium, Copper becomes important as well. Copper has a vital role in the process of photosinthesis, if Copper is not present the two photosinthetic systems are not linked, thus, the absorption of CO_2 and the forming of organic compounds is blocked. Thus, continuous Copper supplementation results in the proper operation of the most important life function.

The 6th treatment (Cosavet DF + KelCare Cu) was a combination of the latter two treatments.

2. 5. Sampling and harvesting

During the research years sugar beet roots and leaf samples have been taken.

Root samples have been collected in the growing season in August (after row closure) and September (after leaves changing), besides, samples have been collected during harvesting.

After appropriate labelling, the samples have been taken in the sugar manufacturing company. Besides analysing the parameters we required (sugar content and Potassium, Sodium and alpha amino Nitrogen content) the company has frozen one part of each root sample to ensure the material for further analysis. During harvesting, sugar beet samples have been weighed separated according to research plots. Furthermore, samples have been weighed in the field thus we found out the average yields by treatments.

Another group of samples was that of the leaf samples, which have been collected according to the literature, at row closure (15 June – 15 July) and during the period of leaf changing (1-30 August). A 3rd sampling period was the first ten days of September. The newly emerged young leaves have been sampled. The element content of the samples were determined at The Central Laboratory of the University of Debrecen.

2. 6. Methods of the analysis

Beet root samples have been taken to the laboratory of Eastern Sugar in Kaba. The analysis of the samples have been conducted by a beet analysing system by VENEMA according to the beet root standard (MSZ 17045:2002). Sugar beet was washed and manually topped. Then beet was grated to get a well representable pulp. 26 g pulp was used for the analysis, to which lead-acetate was given by an automatic distributor, and the filtrate was used to analyse the sugar content and the other qualitative parameters (Potassium, Sodium, alpha-amino Nitrogen content).

The sugar content was determined by Saccharomat automatic saccharometer. Flame photometer was used to determine the Potassium and Sodium content while the alpha-amino-Nitrogen content was determined by spectrophotometer.

The sugar content is given in per cent, the Potassium, Sodium and amino-Nitrogen content is given in mmol 1000 g^{-1} root.

One part of the homogeneous beet samples have been stored frozen. These homogeneous pulps have been used similarly to leaf samples, as follows.

After labelling them according to the research plot, the leaf samples and the pulp samples have been taken to the accredited laboratory of the University of Debrecen, Institute of Food Science, Quality Assurance and Microbiology. The preparation of the samples has started and the samples have been broken up to leaf blade and petiole. After weighing, we put the samples in a 60 °C drying chamber. After drying the samples have been grated to get a homogenious material for the analysis (MSZ ISO 6498:2001, MSZ ISO 6496:2001).

To determine the overall element content of the samples, wet charring was used according to the method of KOVÁCS et al. (1996, 2000). 1 g sample was measured in digestion tubes than 10 ml cc. HNO_3 was added. (50 samples can be digested in one charring block at a time). The samples and the acid was let for a night then put in a heating unit where the pre-digestion has taken place at 60 °C, for 30 minutes. The samples have been removed from the heating unit to cool down and 3 ml cc. H_2O_2 was added. After the hydrogen peroxide reacted, charring was started in the charring heating unit mentioned above at 120 °C for 90 minutes. After charring the samples cooled down and were topped with ion-exchange water to 50 ml. The samples have been homogenized by a laboratory mixer and filtered through filter paper in 100 ml flask. 25 ml of the filtrate was put in numbered scintillation pots.

The first sample in the charring block was the so called blind sample, which was handled according to the upper method with this difference that the sample to analyse was not put in the digestion tube. This method allowed me to find if any contamination got into the sample.

Nitric acid and hydrogen peroxide allows for determining the overall elements within a sample – this method is called wet charring. Optima 3300 DV, ICP-OES equipment was used. This is an optical emission analytical method for the simultaneous analysis of macro- and microelements.

2. 7. Method of evaluation

To analyse the data provided by the sugar factory, one-factor analysis of variance was used. The $LSD_{5\%}$ was calculated according to SVÁB (1981) to determine the margin of error, above which the effect of the analysed factor is proved.

The corrected sugar content was calculated using the data provided by the sugar factory (saccharose content, Potassium, Sodium and alpha-amino-Nitrogen content) according to Reinefeld (REINEFELD et al., 1974).

$$\textbf{corrected sugar content\%} = \textbf{saccharose content\%} - \left[0{,}343 * (\mathbf{K} + \mathbf{Na}) + (\mathbf{0{,}094} * \mathbf{amino} - \mathbf{N}) + 0{,}29\right]$$

The absolute loss was calculated as the difference between the sugar content measured by the factory (saccharose content) and the corrected sugar content. Taken the measured sugar content 100 % I examined the absolute loss, which determines the relative loss. Correlation analysis and linear regression analysis was used to determine the relation between calculated losses and the quality parameters (sugar, Potassium, Sodium and alpha-amino-Nitrogen content).

The analysis of the data provided by the Central Laboratory of the University of Debrecen (analysis of the element content of sugar beet leaves and pulp with ICP-OES), was done by stepwise regression analysis (SVÁB, 1981).

SPSS 12.0 for Windows computer program package was used for the statistical analysis. Microsoft Office Excel 2003 was used to make the diagrams of mean values and deviations.

3. Results and conclusions

3. 1. Qualitative and quantitative parameters of sugar beet and the evaluation of results

One of my objectives was to evaluate the effect of the foliar treatments on the root yield, sugar content, the content of harmful non-sugars, losses (absolute and relative) and last but not least on sugar yield.

Considering the root yield, we found that the lowest yield was harvested on the non-treated plots in both research years (1. treatment – control plots; in 2005 the yield was 65,12 t ha^{-1} t at Béke Agricultural Cooperative on the average of the replicates of the treatment, at Hajdúböszörményi Agricultural Plc. the yield was 74,65 t ha^{-1}, while in 2006-ban it was 43,21 and 77,98 t ha^{-1}, respectively). Statistically significant difference was found between the treatments.

Figure *1 and 2 show* the results of the treatments.

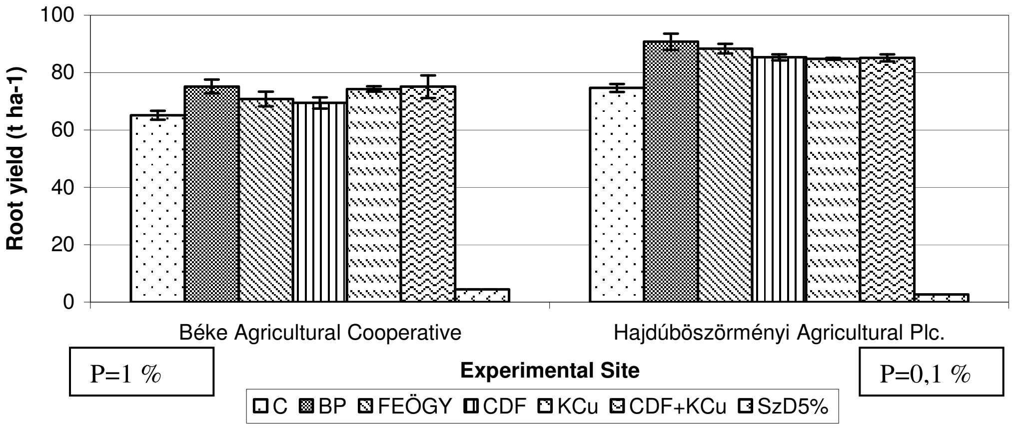

Figure 1: Root yield in 2005 (Béke Agricultural Cooperative, Hajdúböszörményi Agricultural Plc.)

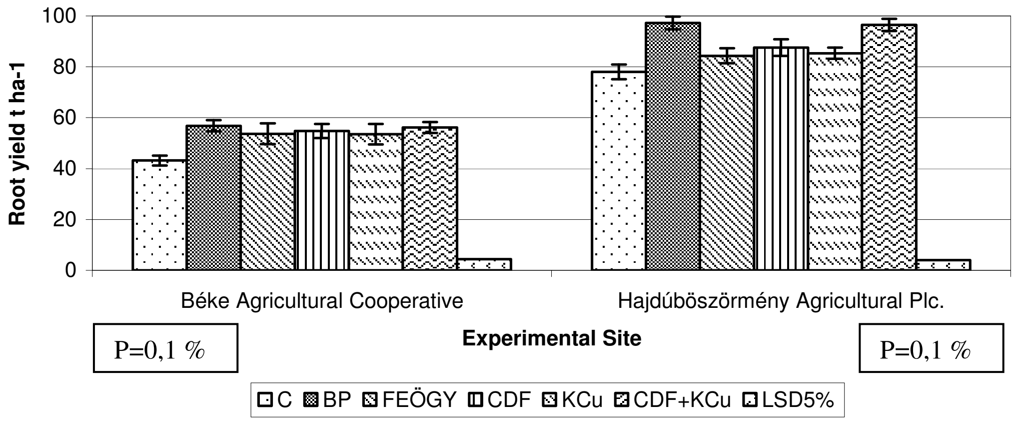

Figure 2: Root yield in 2006 (Béke Agricultural Cooperative, Hajdúböszörményi Agricultural Plc.)

As regards sugar content measured in the two years, we found on both experimental sites that the sugar content from plots treated according to the usual practice was lowest at all three sampling. Comparing, each treatments resulted in extra sugar content; however, this plus amount was not statistically proved for each sampling. The result of the variance analysis proved significant difference (P=10%), thus we can state that in both research years and at both experimental sites the outstanding treatments are those where the sulphur-containing compound was given during row closure (treatments 4 and 6 – Cosavet DF and Cosavet DF + KelCare Cu).

As regards the amount of harmful non-sugars, based on the two research years we found that we cannot draw obvious conclusions for the Potassium content on the two experimental sites. Sodium and alpha amino Nitrogen proved to be outstanding both in treatments 4 and 6 (Cosavet DF and Cosavet DF + KelCare Cu).

Based on the data provided by the sugar factory, we calculated the expected losses caused by nonsugars during the process by means of the Reinefeld formula according to the experimental site and the treatment. The calculated absolut loss is the difference between the sugar content measured by the factory and the cleaned sugar content calculated according to the formula. The relative sugar loss means that the absolute loss when measured sugar content is taken 100%., Examining the efficiency of production we also found that, the highest losses have been measured on the control plots. Statistically lower values have been realized by treatments 4 (Cosavet DF) and 6 (Cosavet DF + KelCare Cu), where, - either itself or combined with other components - Sulphur has been given, similarly to our finding concerning sugar content.

The question arises which non-sugar components have significant role in the two types of losses. Examining the correlation between the losses and the harmful non-sugars I found that the Sodium and the alpha amino Nitrogen content has important role (in case of the Sodium content and the calculated losses R^2 =0,86-0,98; for alpha amino-Nitrogen content ranges between 0,47-0,80. There was no statistically proved correlation between the Potassium content of the beet and the losses (absolute and relative) for either experimental sites.

Total gross and net sugar yield was calculated from the sugar beet yield, the sugar content measured by the factory and the corrected sugar content determined by us according to the Reinefeld formula. The examined indexes summarize the correlation between the average yield, sugar content and the non-sugars. Since significant difference was found between the treatments regarding the net and gross sugar yield, the treatments contributed to the increase of sugar yield per hectare. As regards sugar yield the smallest yields (both net and gross sugar yield) were harvested from the control plots at both experimental sites in both years.

The outstanding treatments are those where the sulphur-containing compound was applied. Figure *3. 4. 5. 6.* show the sugar yield values.

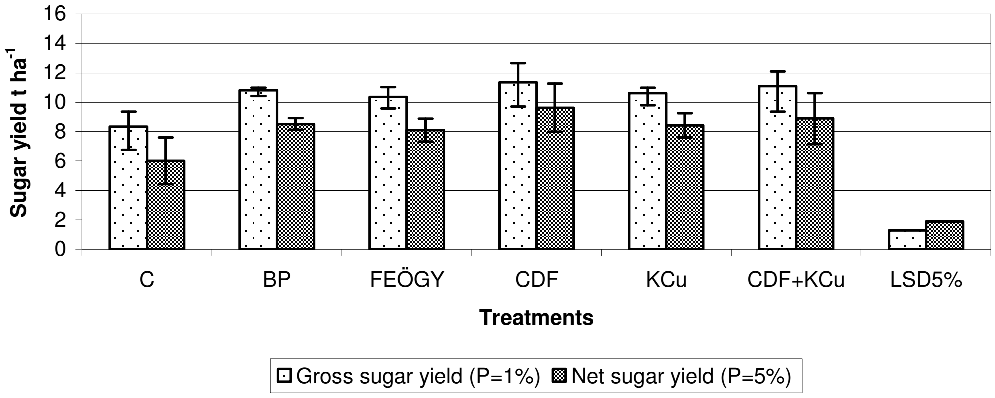

Figure 3: Gross and net sugar yield (Béke Agricultural Cooperative, 2005)

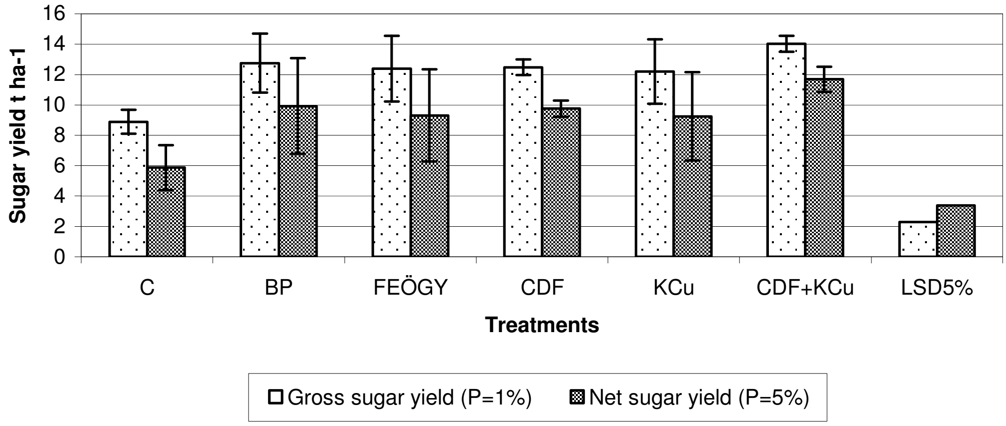

Figure 4: Gross and net sugar yield (Hajdúböszörmény Agricultural Plc., 2005)

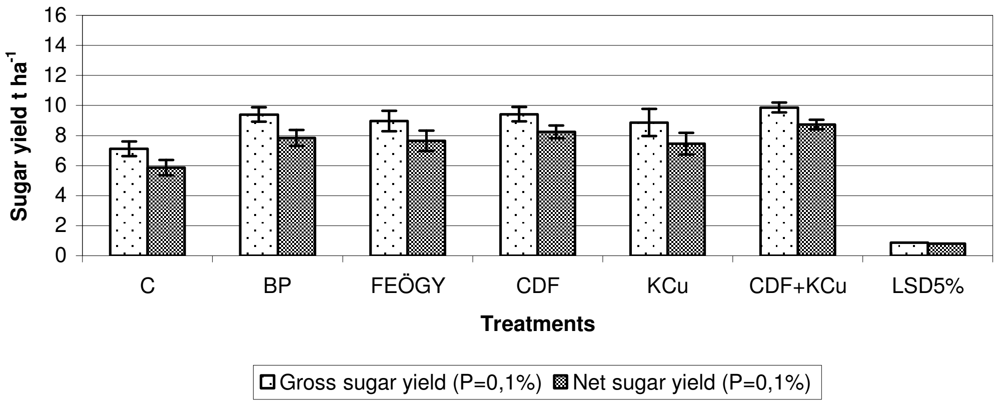

Figure 5: Gross and net sugar yield (Béke Agricultural Cooperative, 2006.)

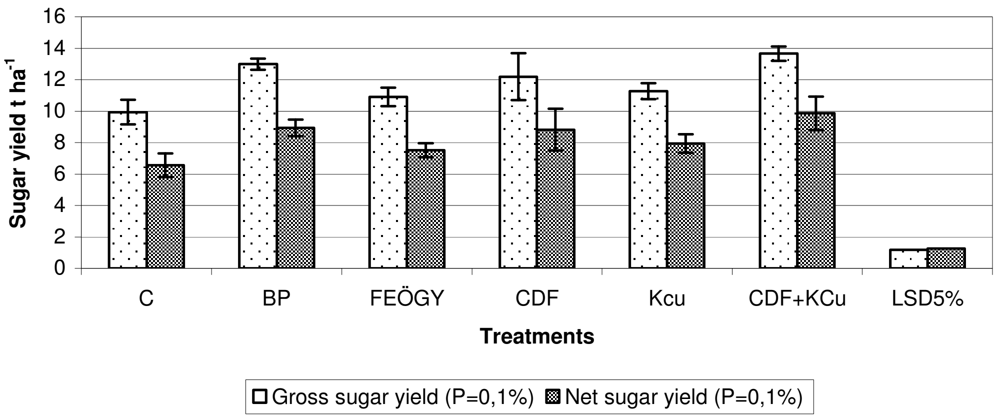

Figure 6: Gross and net sugar yield (Hajdúböszörmény Agricultural Plc., 2006.)

3. 2. Statistical evaluation of results from leaf and beet analysis

3. 2. 1. Sampling method of sugarbeet leaf

Another important group of our results is the evaluation of leaf and beet analysis data.

We followed the method commonly used in literature, i.e. we analysed the leaf blade and petiole separately. Considering the high amount of data, the question arised whether it is worthwile to follow this method. Therefore, being aware from the literature that the petiole of sugar beet acts as a depot of mobile elements, during the statistical evaluation we looked for correlation between the element content of the leaf blade and petiole (JONES, 1967; WILCOX and COFFMAN, 1972).

There was a weak – medium-strong correlation (R^2=0,1-0,5 and R^2=0,1-0,7) for the Nitrogen and the Potassium content between the leaf blade and the relating petiole, while for phosphorus, this correlation was medium-strong – strong (R^2=0,3-0,8). We found a weak-medium strong correlation (R^2=0,1-0,7) for calcium and medium strong-strong correlation for strontium (R^2=0,4-0,8).

The reason for the strong correlation for the latter two elements might be the fact that the mineral composition of Nitrogen, phosphorus and Potassium fertilizers available for the plants and used in agricultural practice might be more diverse than we think. The composition of chemical fertilizers primarily depends on the place of origin, the processing circumstances, the by-products of production and last but not least the supporting elements given. KÁDÁR (1991) found that Nitrogen fertilizers, besides supplying Nitrogen, can supply Ca and Sr as well. Phosphorus fertilizers might contain stroncium in percentals due to the high strontium content of the raw material, raw phosphates. Some of the analysed Potassium fertilizers contained Ca in percentals, and even heavy metals have been detected in trace amounts. Concluding, besides the three major macroelements some others are also supplied, therefore their content in the petiole and the leaf blade is relatively stabil (Table 4 and 5).

Table 4: Pearson's correlation r values showing the correlation between the phosphorus content of the petiole and the leaf blade, among the experimental sites, years and sampling

Year	Site	1st sampling	2nd sampling	3rd sampling
2005.	**Béke Agric. Coop.**	0,704***	0,819***	0,899***
	Hb. Agricultural Plc.	0,186	0,700***	0,774***
2006.	**Béke Agric. Coop.**	0,722***	0,854***	0,586**
	Hb. Agricultural Plc.	0,667***	0,908***	0,634**

Significance levels: +P=10%, *P=5%, **P=1%, ***P=0,1%

Table 5: Pearson's correlation r values showing the correlation between the strontium content of the petiole and the leaf blade, among the experimental sites, years and sampling

Year	Site	1st sampling	2nd sampling	3rd sampling
2005.	**Béke Agric. Coop.**	0,702***	0,908***	0,710***
	Hb. Agricultural Plc.	0,656**	0,802***	0,872***
2006.	**Béke Agric. Coop.**	0,792***	0,837***	0,872***
	Hb. Agricultural Plc.	0,894***	0,904***	0,680***

Significance levels: +P=10%, *P=5%, **P=1%, ***P=0,1%

Considering the correlation of the analysed factors, we concluded that separate sampling of the leaf blade and the petiole is suggested.

3. 2. 2. The result of the sugar beet leaf and beet pulp analysis

The research work of the last decades revealed that it is not enough to analyse the soil, but also the soil-plant system has to be studied to satisfy the nutrient supply of a given plant culture.

The results of the plant analysis have been compared to the data of the Institute of Plant Nutrition in Jena (ELEK and KÁDÁR, 1980), allowing for the evaluation of the nutritional state of a given plant culture. Their results refer to young leaf blade without the petiole, and the sampling period was the end of June, beginning of July, i. e. the period of row closure. The following table shows the calculated and estimated optimum levels (Table 6).

Table 6: Limit values of plant analysis of sugar beet (Institute of Plant Nutrition in Jena)

Element	**Very low**	**Low**	**Satisfying**	**High**	**Very high**
N %	< 2,50	2,50-3,50	3,60-4,00	> 4,00	
P %	< 0,20	0,20-0,30	0,31-0,60	> 0,60	
K %	< 0,50	0,50-1,99	2,00-6,00	> 6,00	
Ca %	< 0,10	0,10-0,49	0,50-1,50	> 1,50	
Mg %	< 0,05	0,05-0,24	0,25-1,00	> 1,00	
Mn mg kg $^{-1}$	<10,00	10,00-25,00	26,00-360,00	> 360,00	
Zn mg kg $^{-1}$	< 5,00	5,00-9,00	10,00-80,00	> 80,00	
Cu mg kg $^{-1}$		<9,00	9,00-13,00	> 13,00	
B mg kg $^{-1}$	<20,00	20,00-30,00	31,00-200,00	201,00-800,00	>800,00
Mo mg kg $^{-1}$	< 0,10	0,10-0,19	0,20-2,00	2,10-20,00	> 20,00

Sampling period: end of June, beginning of July, young leaf blade

These limit values have been compared to the element content of our samples from the same period, i. e. the leaf samples of the 1st sampling. The results are shown in Table 7. We found that the measured values of plant analysis range in the satisfying intervall for almost every elements.

There was no extremely low or high amount found for the analysed elements.

Table 7: The result of the leaf blade analysis regarding the year and the site

	Average of treatments			
Year	**2005**		**2006**	
Site	**Béke Agric. Coop.**	**Hb. Agricultural Plc.**	**Béke Agric. Coop.**	**Hb. Agricultural Plc.**
Analysed element	1st sampling (end of June – beginning of July)			
N %	4,19*	4,00	3,66	3,88
P %	0,34	0,39	0,25**	0,39
K %	2,68	2,43	1,98**	1,63**
Ca %	0,81	0,79	0,81	0,65
Mg %	0,59	0,75	0,67	0,81
Mn mg kg $^{-1}$	274,15	147,25	40,11	35,16
Zn mg kg $^{-1}$	32,1	39,88	34,8	40,06
Cu mg kg $^{-1}$	12,96	10,35	10,84	11,21
B mg kg $^{-1}$	52,64	42,95	58,82	52,24
Mo mg kg $^{-1}$	1,98	1,84	1,69	1,61

* high ** low

Knowing the limit values of the plant analysis of samples from 2-2 sites in a year, and the element content of the leaf blade, petiole and beet pulp, we looked for further correlations between the concentration of a given element or element group at a given time period and that of yield, harvesting quality (sugar content, Potassium, Sodium and alpha amino Nitrogen content) and the gross and net sugar yield per hectare.

The statistical analysis was stepwise regression analysis, allowing for the examination of dependent variable caused by the independent variables. The dependent variable are root yield, sugar yield, and the quality parameters mentioned above, the independent variables are the parameters of the analyis of the petiole, leaf blade and sugar beet pulp.

Considering the two research years and the two-two sites, we could not draw an obvious conclusion regarding the sequence of the analysed variable. Thus, our assumption whether there is an element or a sequence of elements that would determine the major quality parameters already in the growing season, was not statistically proved.

However, we have taken into consideration that the evaluation included all the six treatments with the replicates.

Thus, we concluded that the effects of the different treatments might bias the final results. Therefore, by means of the statistical method mentioned above, we examined the replicates of the control plots as well. Again, we could not draw an obvious conclusion regarding the individual elements and the harvested yield, quality and quantity of sugar.

Summarizing, we found that the knowledge of elements allows for the estimation of the status of plant nutrition (similarly to the limit values of the Institute of Plant Nutrition in Jena) and evaluation of the culture already at the first sampling. However, we cannot draw conclusions reagarding root yield, harvesting quality (sugar content, Potassium, Sodium and alpha amino Nitrogen content), and sugar yield (both gross and net).

New and novel scientific results

1. Nutrient application - containing microelements - proved to be most beneficial for the yield. Yield increases were statistically proved.

2. Treatments with Sulphur containing agent decreased the absolute and relative sugar loss, with a statistically proved extent.

3. Foliar fertilizers containing microelements maintained sugar content and statistically increased sugar beet yield, compared to those sites where the regular farm practices have been used. In those treatments where sulphur-containing foliar fertilizer was applied, the high sugar content contributed to higher sugar yield. The difference in net and gross sugar yield was statistically proved.

4. Considering the effectiveness of sugar production, the rate of sugar loss (both net and gross) was determined by Sodium and the harmful Nitrogen.

5. We did not find statistically proved answer for the question whether the concentration of petiole samples measured at a given time in the growing season can indicate the state of the main quality parameters at harvesting time (sugar content, Potassium, Sodium, alfa amino Nitrogen, and gross and net sugar content).

6. Statistical method used stepwise regression analysis did not show significant correlation between the element content of beet pulp samples and the parameters determining the product yield and quality at harvesting time.

7. The results of the leaf analysis have been used to look for correlation between the element content of the petiole and leaf blade. We found that, as literature also states - the separate analysis of the leaf blade and petiole is suggested.

Results can be used in practise

1. Foliar fertilizers can be mixed with genereally used pesticides, therefore can be spayed simultaneously.

2. The leaf analysis in the growing season at the time of row closure might be useful to estimate the nutrient supply of a given plant culture.

3. Supplementing the usual nutrient supply with commonly available sugar beet fertilizers in the form of foliar treatment, significant increase can be generated in the sugar yield.

List of publications in the topic of the dissertation

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