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EVALUATION OF THE FOLIAR NUTRITION INFLUENCE ON SELECTED QUANTITATIVE AND QUALITATIVE PAPRAMETERS OF SUGAR MAYZE (*ZEA MAYS* SK *SACCHARATA*)

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ABSTRACT
We evaluated the effect of foliar application of fertilizer Tecnokel amino Zn on selected quantitative (weight of one corn cob, average length of corn cob, number of grains per row and number of rows per cob) and qualitative (total yield, total carotenoid content, total sugar content) parameters of sweetcorn. The small trail experiment was founded in 2016 in the Botanical Garden of the Slovak University of Agriculture. We observed 7 selected varieties of sweetcorn and two variants: control and with leaf nutrition. 15 plants we revaluated for each variety under both variants. The corn was grown in three repetitions for each variant. Based on the obtained results, we found that both the qualitative and quantitative parameters were mainly dependent on the genotype. Statistically significant was effect of the variety on the total sugar content in maize grains. Influence of foliar nutrition was not confirmed as statistically significant, but Tecnokel amino Zn has a positive impact on several quantitative parameters as weight of one maize ear or average length of corncobs. Content of total carotenoid doesn´t depend on genotype or variant.

Keywords: sweet corn; carotenoids; total sugars; zinc; foliar application

INTRODUCTION
Sweet corn, also known as green maize or sweet maize in many parts of the world, is a crop of New World origin **(Welbaum, 2015)**. It is one of the oldest crops cultivated on the world. Indigenous people in both Americas have known corn as early as 5000 years ago **(Černý, 2011)**. Now, the USA is a leading producer of sweet corn with 236,860 ha with production totalling 3,788,030 metric tonnes. In Slovakia we have sweet corn production with only 1,110 ha and total yield 7,498 t **(Meravá, 2017)**. Sweet corn (*Zea mays* L var. *saccharata* Strut) is one of several types of maize, which also includes flint corn, dent corn, popcorn, flour corn, and pod-corn but sweet corn differs from other corns. The primary difference is gene expression that determines endosperm carbohydrate content as well as many other genes that affect maize growth. Sweetcorn world consumption has increased over the past 30 years. As consumable part are grains of milk ripeness, while production is focused on three distinct markets: fresh, canning, and freezing **(Alan et al., 2014; Andrejiová and Šlosár, 2015; Khan et al., 2018)**. *Z. mays* var. *saccharata* is a warm-season, frost sensitive, annual monocot which belong to family *Poaceae*. For reaching high yields it´s necessary harmonic and balanced effect of all agroecological factors. Accurate growth and development depend on suitable temperatures and proper water regime in deep humous soils **(Welbaum, 2015)**. In animals, carotenoids are the precursors for vitamin A and serve as important antioxidants to prevent many diseases such as cardiovascular disease, cancer and light-induced erythema. Studies have also shown that dietary intakes of lutein and zeaxanthin can reduce the risks of cataracts and age-related macular degeneration (AMD), which is the leading cause of blindness among the elderly. Corn is one of the essential sources of these carotenoids, contains significant amounts of lutein, zeaxanthin, and other carotenoids. Carotenoid content of sweetcorn can reach up to 1,978 $mg.g^{-1}$ of fresh weight. In recent years, many studies have been carried out on carotenoids in sweetcorn. They observed several parameters, among them changes of carotenoids in sweetcorn during thermal processing or the quantification of carotenoids in different genotypes of sweet corn **(Liu et al., 2017; Scott and Eldridge, 2005)**. Sweetness is the major component of flavour affected by the amounts of sugar and starch in the endosperm. Selection more tender and crispy genotypes with higher sugar, lower starch concentration and more intensive sweet corn aroma would increase the eating quality of the product. But sweetness is determined not only by genetics, but also by the agronomics practices, how the respective varieties are managed and harvested **(Alan et al., 2014)**. Zinc (Zn) is an essential micronutrient for plant life and it is a recommended micronutrient in fertilizer programs for production of corn and sweet corn **(Sutradhar, Kaiser and**

Fernándeza, 2017). To fully explore grain production potential of sweet corn, it is essential to know how plants interact morphologically and physiologically in a community and to realize management practices, which allow them to utilize growth resources in their environment **(Hayat et al., 2018)**.

Scientific hypothesis

Foliar application of Tecnokel Amino Zn had not a significant effect on the qualitative and quantitative parameters of corncob. Used preparation positively affected sugar content and the ear of maize size while carotenoids were not negatively affected. The influence of the variety was statistically significant.

MATERIAL AND METHODOLOGY

The trial establishment

An experiment was founded in 2016 in Botanical Garden of Slovak University of Agriculture (below BG SUA) in the field conditions. Area is situated in very warm agro-climatic region, very dry sub-region. The mean annual temperature was 10 °C (Table 1) with average annual rainfalls 62.4 mm per month (Table 2). Meteorological measurements were carried out by the help of meteorological station in the area of botanical garden, SUA in Nitra. The mean monthly air temperature and average rainfall for the year 2016 were evaluated by the climate normal 1961 – 1990.

In the experiment we investigated the effect of foliar nutrition with Tecnokel Amino Zn on selected quantitative and qualitative parameters in the following variants:

- 1st variant (C) – (control) without applying of Tecnokel Amino Zn.
- 2nd variant (Tecnokel Amino Zn) – foliar application of Tecnokel Amino Zn.

For both variants, based on the agrochemical analysis of the soil and the recommended normatives for the cultivation of sweet corn, we applied nitrogen one week before sowing in the form of nitrogen fertilizer LAD (27% N) (60% of the recommended normatives for corn) at a dose of 72 kg.ha^{-1}. When plants were 50 cm tall, we applied 40% of recommended LAD normative (27% N) in dose 48 kg.ha^{-1}.

Sowing the seeds was into pre-prepared soil on April 26, 2016. Before sowing, we made soil air spacing and removed the weeds. The seeds were sown in space 0.8 m between rows and 0.3 m within rows. During the vegetation. the supplementary irrigation was applied, as well as loosening and weeding of the crop. As corn tended to expel side shoots, we removed them on 8 June.

In the growth phase of 6 – 8 true leaves, (06.06.2017) we applied foliar fertilizer Tecnokel Amino Zn, which plays a key role as a building material and a regulating factor of wide range of enzymes and positively influences the transport of substances in the plant. The dosage of application was 30 mL.10L^{-1} of water applied to the Tecnokel Amino Zn variant. The second application of Tecnokel Amino Zn with dosage 30 mL.10L^{-1} of water was carried out on 21st July after flowering.

Harvesting of sweet maize ears was carried out gradually according to the maturation of individual varieties, in the period from 26th July to 1st August in the milky matured grains stage. Within each variety we evaluated 15 plants from the control and 15 from Tecnokel Amino Zn variant.

Table 1 Evaluation of the mean monthly air temperature 2 m above ground within the selected months in 2016, according to climatology normal 1961 – 1990.

	t [ºC]	Normal 1961-1990	Δt [ºC]	Characteristic
V.	15.0	15.1	-0.1	Normal
VI.	20.3	18.0	2.3	Extra Warm
VII.	21.4	19.8	1.6	Warm
VIII.	19.5	19.3	0.2	Normal
IX.	17.5	15.6	1.9	Warm

Table 2 Evaluation of monthly total rainfalls in selected months in 2016, according to climatology normal 1961 – 1990.

	Z [mm]	Normal 1961-1990	% of normal	Characteristic
V.	91	58	157	Extra Wet
VI.	14	66	22	Extremely Dry
VII.	135	52	259	Extremely Wet
VIII.	35	61	57	Dry
IX.	37	40	92	Normal

Table 3 Summary of the observed maize genotypes.

Variety	Supplier	Origin
SF 648 F1	Strube	Spain
Rising sun F1	Strube	Australia
Astronaut	Strube	Australia
ZHY 1312 OR	Strube	Spain
Escalate	Strube	Australia
ZHY 0874 OV	Strube	Spain
Overture	Strube	Australia

Table 4 Agrochemical characteristics of the soil before the foundation of the experiment in 2017.

pH/KCl	humus %	Nutrients content in mg.kg^{-1} of the soil					
		N_{an}	P	K	S	Ca	Mg
7.14	4.17	13.0 M	198.8 VH	487.5 VH	2.5 VH	610 H	816 VH

Note: Nutrient content: M – medium content, H – high content, VH – very high content.

Evaluation of selected quantitative parameters:

In the labs of the Department of Vegetables production at SUA we evaluated the following parameters: weight of one corn cob, length of corn cob, the number of grains per row and the number of rows per cob. Based on the average weight of maize cobs and cultivation spacing, the total yield was calculated.

Laboratory analyses – qualitative parameters

Qualitative characteristics were estimated in the laboratory of Department of Vegetable Production, SUA, in Nitra. For laboratory analysis were used only fresh corn ears in phase of milk grains within of all observed varieties. Weight of one sample – 20g. Both control as well as the Tecnokel Amino Zn variant were observed. Fresh fruit analysis took a place directly after each harvest. Total carotenoids were estimated by spectrophotometric measurement of substances absorbance in petroleum ether extract on spectrophotometer PHARO 100 at 450 nm wavelengths according to **Hegedüsová et al. (2015)**. The determination of total sugars according to **Somogyi (1952)** was carried out at the Department of Agrochemistry and Plant Nutrition.

Statistical analysis

The analysis of variance (ANOVA), the multifactor analysis of variance and the multiple Range test were done using the Statgraphic Centurion XVII (StatPoint Inc. USA).

RESULTS AND DISCUSSION

Total carotenoids

The content of total carotenoids in selected varieties of sweet corn grains without foliar application of Zn ranged from 0.75 to 1.35 mg.100g^{-1} of fresh matter. In the Tecnokel Amino Zn variant, the values ranged from 0.65 to 1.83 mg.100g^{-1}. The highest content of total carotenoids was recorded in the variety Escalante 1.83 mg.100g^{-1} for observed variant. The positive influence of Zn on the content of total carotenoids was observed in varieties Rising Sun, Astronaut, ZHY 1312 OR, Escalate and ZHY 0874 OV (Figure 1). In different experiment **Howe and Tanumihardjo (2013)** reported higher carotenoid content in four varieties of sweet corn ranged from 0.99 to 3.53 mg.100g^{-1}.Based on statistical evaluation of our data obtained by the multifactor analysis of variance, we can state that the variant hadn´t significant influence on the total carotenoids content in fresh corn grains (Figure 4). Effect of the variety on the total carotenoid content wasn´t statistically significant.

Total sugars

Based on the results, we can conclude that all evaluated varieties of sweet corn belong to the Sh-2 group with a storage period of 4 – 7 days. The total sugar content ranged from 3.85% to 8.60% what is comparable with results of **Zaniewicz-Bajkowska et al. (2010)**. They observed the total sugars content in sweet corn in range from 5.61% to 9.02%. In our experiment, the lowest content was recorded for variety ZHY 1312 OR 3.85%. Overture variety obtained highest value of 8.60% (Figure 2). By foliar application of Tecnokel amino Zn at a dose of 30 mL.10L^{-1} of water, we found that the ingested preparation had no statistically significant effect the increase of total sugars in corn grains (Figure 5). Based on statistical analysis, we can conclude that the genotype has a significant effect on the total sugars in the grains at the stage of milk maturity.

Total yield

Haytova (2013) in her review referred that additional foliar application during the growth and development of crops can improve their nutrient balance, which may lead to an increase in yield and quality of crops. Harvesting of maize in our experiment proceeded gradually according to maturation of individual varieties. The average calculated yield achieved in individual varieties and variants is compared in (Figure 3).

During the evaluation of total corn cob yield, we found that within the control variant, total yield ranged from 8.97 t.ha^{-1} in SF 681 variety to 12.52 t.ha^{-1} in Escalate variety. However, the highest hectare yield was 13.14 t.ha^{-1} for the Overture variety without the application of the foliar fertilizer. Similar result was observed also by **Rosa (2015)**, where the average marketable ears yield was 13.0 t.ha^{-1}. The lowest yield per hectare in our experiment reached the SF 681 variety with 8.97 t.ha^{-1}. However, the greatest difference between crops was recorded for the ZHY 1312 variety in favour of the Tecnokel Amino Zn variant 24.01% (Figure 3). Similar results stated also **Fahrurrozi et al. (2016)**. In their study additional foliar fertilization of sweet corn did not significantly influenced growth and yield. **Szczepaniak et al. (2018)** event stated that zinc (Zn) fertilizers applied to maize simultaneously with amino acids (AA) at early stages of its growth may decrease the yield variability due to correcting its nutritional status during the 'critical window' but simultaneously confirm the benefits in order to ameliorate the influence of abiotic stress. However, this combination has positive effect on lettuce plants **(Ghasemi et al., 2013)**. **Grzebisz et al. (2008)** wrote that according to other authors maize plants responded to zinc fertilizer and yielded 10 – 20% more. It supported by positive result of **(Tariq et al., 2014; Liu et al., 2016; Ruffo et al., 2016, Shabaz et al., 2015)**. However, our result may be influenced by an inappropriate proportion of the nutrients applied. **Shabaz et al. (2015)** concluded that this significant enhance of corn yield is because trace elements had a synergic affiliation with other units. **Wang et al. (2017)** and **Iqbal et al. (2016)** also state that Zn combined with K or N can slightly or significantly increased grain yield. The influence of Zn uptake and its effect on corn yield depends on Zn supply in soil **(Eteng et al., 2014)**, what should caused our results. All these results are in consonance with **da Silva et al. (2017)** exhibited increase in corn yield by 0.342 t.ha^{-1} with 83.7% probability of positive response after foliar application of amino acid bio stimulant. **Popko et al. (2018)** confirmed these results. Amino acids bio stimulants increased wheat grain yield and agronomic productivity.

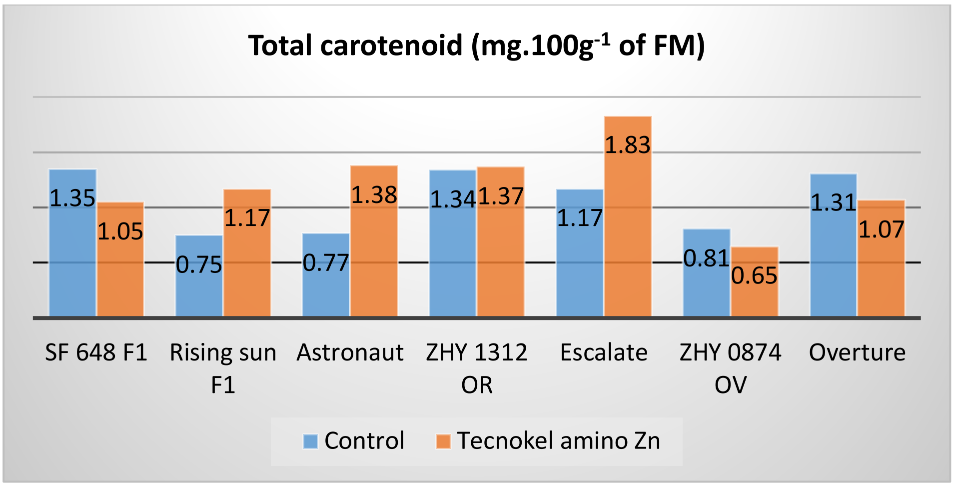

Figure 1 Total carotenoids content (mg.100g^{-1} of fresh matter) in sweet corn grains depending on the observed maize varieties and variants (Nitra, 2017).

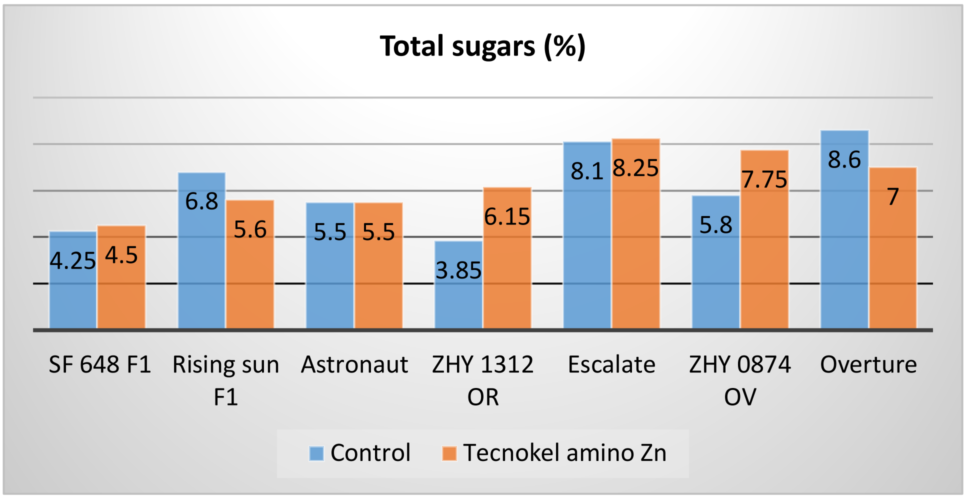

Figure 2 Total sugars content (%) in sweet corn grains depending on the observed maize varieties and variants (Nitra, 2017).

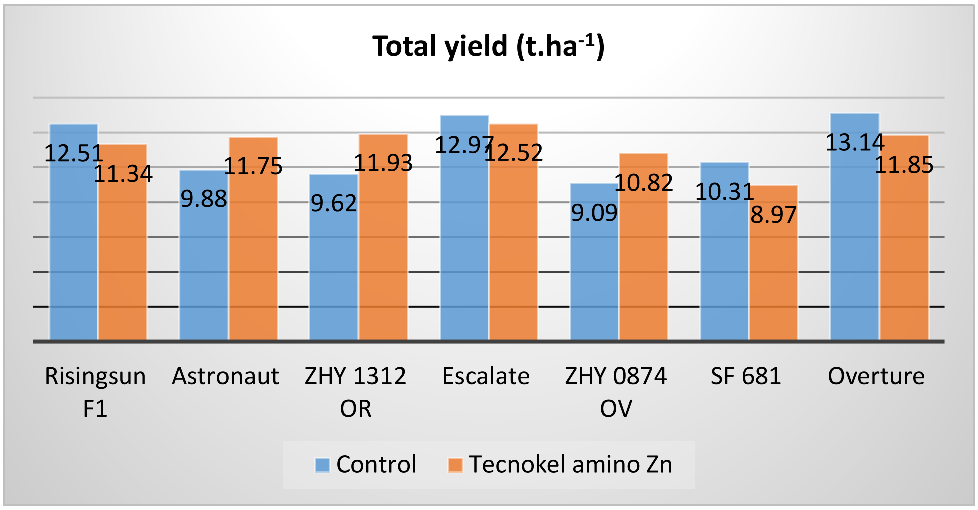

Figure 3 Total yield (t.ha^{-1}) of sweet corn ears depending on the observed maize varieties and variants (Nitra, 2017).

Table 5 Average ear of maize weight (g) depending on the observed maize varieties and variants* (Nitra, 2017).

Variety/variant	C	Tecnokel amino Zn	Difference (%)
Risingsun F1	300.4 ±24.36 c	272.2 ±25.25bc	-9.36
Astronaut	237.3 ±22.81 ab	282.1 ±34.73 cd	+18.87
ZHY 1312 OR	231.1 ±23.82 ab	286.4 ±19.76 cd	+23.92
Escalate	311.4 ±35.38 c	300.6 ±43.12 d	-3.47
ZHY 0874 OV	218.3 ±33.30 a	259.7 ±14.91 b	+18.96
SF 681	247.5 ±16.40 b	215.5 ±20.14 a	-12.93
Overture	315.5 ±30.39 c	284.5 ±26.25 cd	-9.99

Note: *Average ±standard deviation. The different letters of alphabet listed with the mean values in the columns represent statistically significant differences between the observed varieties (p <0.05).

Table 6 Average ears of maize length (cm) depending on the observed maize varieties and variants* (Nitra, 2017).

Variety/variant	C	Tecnokel amino Zn	Difference (%)
Risingsun F1	22.3 ±1.14 c	23 ±0.73 d	+3.13
Astronaut	19.3 ±1.44 ab	19.4 ±0.99 a	+0.51
ZHY 1312 OR	19.9 ±0.54 a	19.4 ±0.75 a	-2.52
Escalate	25 ±0.96 d	24 ±1.14 e	-4.00
ZHY 0874 OV	19.8 ±0.82 b	20.1 ±0.65 ab	+1.51
SF 681	19.9 ±0.54 b	20.2 ±0.86 b	+1.50
Overture	21.9 ±0.59 c	22.3 ±1.23 c	+1.82

Note: *Average ±standard deviation. The different letters of alphabet listed with the mean values in the columns represent statistically significant differences between the observed varieties (p <0.05).

Table 7 Average number of rows in one ear of maize, depending on the observed maize varieties and variants* (Nitra, 2017).

Variety/variant	C	Tecnokel amino Zn	Difference (%)
Risingsun F1	17 ±1.76 a	16 ±1.03 a	+2.58
Astronaut	20 ±0.97 c	20 ±2.15 d	+1.01
ZHY 1312 OR	20 ±1.79 cd	20 ±1.53 cd	-1.99
Escalate	18 ±1.34 b	18 ±1.30 b	+2.25
ZHY 0874 OV	19 ±1.35 c	18 ±1.35 d	-4.24
SF 681	19 ±1.71 c	19 ±1.38 bc	-3.11
Overture	21 ±1.66 d	19 ±1.43 bcd	-8.62

Note: *Average ±standard deviation. The different letters of alphabet listed with the mean values in the columns represent statistically significant differences between the observed varieties (p <0.05).

Table 8 Average number of grains in one rowdepending on the observed maize varieties and variants* (Nitra, 2017).

Variety/variant	C	Tecnokel amino Zn	Difference (%)
Risingsun F1	41 ±2.32c	40 ±2.50 b	-1.47
Astronaut	37 ±1.23 b	38 ±1.72 a	+2.17
ZHY 1312 OR	34 ±2.70 a	38 ±2.12 a	+10.81
Escalate	49 ±1.18 e	48 ±2.40 d	-1.65
ZHY 0874 OV	38 ±1.38 b	41 ±1.24 b	+6.86
SF 681	41 ±1.53 c	40 ±1.68 b	-1.97
Overture	44 ±1.73 d	43 ±2.55 c	-3.41

Note: *Average ±standard deviation. The differnt letters of alphabet listed with the mean values in the columns represent statistically significant differences between the observed varieties (p <0.05).

Foliar supply of Zn in the form of complexed with amino acids resulted in a significant increase of total yield and quality also for other species, for example pistachio nuts **(Najizadeh and Khoshgoftarmanesh, 2018)** or soybean **(Teixeira et al., 2018)**. Using the statistical analysis of variance, statistically significant differences in total yield were not proven between the evaluated varieties or variants.

Ear of maize weight

The weight of the corn cobs is one of the most important features for growers when choosing the right variety of sweet corn. During evaluating the weight of the cobs, we found that the highest average weight reached the variety Overture 315.5 g. The lowest average weight was recorded for variety ZHY 0874 OV 218.3 g (Table 5). In the Tecnokel

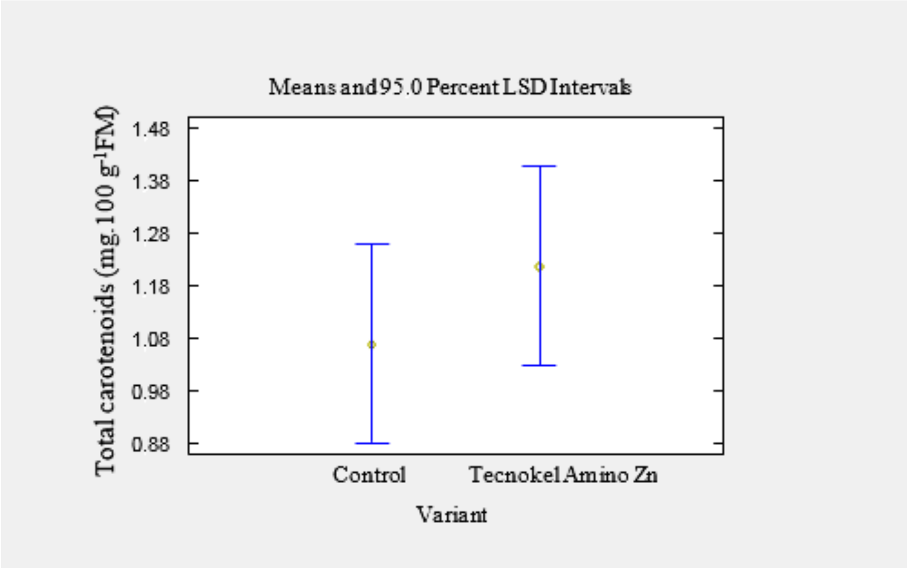

Figure 4 Graphical representation of 95% confidence intervals (p >0.05) for the tested averages of carotenoids content in fresh sweet corn grains and its variants (LSD test).

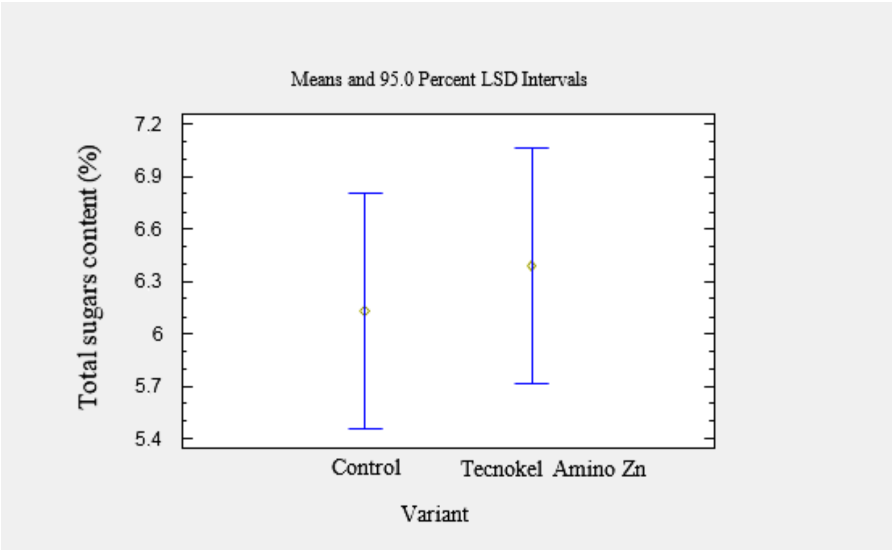

Figure 5 Graphical representation of 95% confidence intervals (p >0.05) for the tested averages of total sugar content in fresh sweet corn grains and its variants (LSD test).

Amino Zn variant, we noted an increase in the weight of the maize-ears for 3 genotypes: Astronaut (by 18.87%), ZHY 0874 OV (by 18.96%) and ZHY 1314 OR where foliar fertilization involved to the highest ears weight grain by 23.92% with average value of 259.7 g. By statistical analysis, we found a statistically demonstrable effect of the variety (genotype) on the weight of the maize ears. We also found that foliar application of Tecnokel Amino Zn fertilizer did not have a statistically significant effect overall, but significantly influenced some individual varieties (Table 5).

Ear of maize length

Barátová (2012) in her work reported results from the evaluation of 8 different varieties of sweet corn. Their ear length ranged from 18 cm to 21 cm. The average length of the strains in our experiment was quite similar and ranged from 19.3 cm to 25 cm. Highest value was caused by extremely long genotype Escalante, which reached average length of corn cobs 25 cm for control and 24 cm for Tecnokel amino Zn variant (Table 6). Due to the foliar application of fertilizer, we observed a slight increase in length for five varieties: Rising sun F1 3.13%, Astronaut 0.51%, ZHY 0874 OV 1.51%, SF 681 1.50%, Overture 1.82%. Statistical evaluation of results showed a statistically significant influence of the variety on ears length (Table 6), but the application of foliar fertilizer Tecnokel Amino Zn did not have a statistically significant effect on the length of corn cobs. It was similar in study **Tadros et al. (2019)** where foliar application of amino acid bio stimulant on sweet corn did not show significant effect on sweet corn ears.

Number of rows in one ear of maize

Strube D&S GmbH gives the following characteristics for cultured genotypes: Rising sun F1 – 14, Astronaut – 20, ZHY 1312 OR – 20, Escalate – 18, ZHY 0874 OV – 18, SF 681 – 20, Overture – 20. For sugar corn, the number of rows in the ear should be even. In our experiment we recorded average number of rows in the interval between 16 – 21 rows. The highest average value in the number of rows in width 21, was recorded in the Overture variety. By applying zinc to this variety, we have not seen any greater increase in the number of rows. The smallest average values were recorded for the variety Rising sun F1 with 16 rows, but this is more than what the seller report. Also, for variety Overture was measured 8.62% fall in number of rows compared to variant with foliar fertilizer (Table 7). Average values obtained from our tested maize ears were comparable with **Barátová (2012)**. She referred that the average number of rows in ranged with the width of 16 – 18. After statistical analysis of the variance, we found a statistically significant effect of the variety on the number of rows in the ear, but at the same time the effect of the foliar fertilizer Tecnokel Amino Zn was not significant (Table 7).

Number of grains in one row

Number of grains in one row ranged between 34 – 49. The highest average values obtained genotype Escalate with yield 49 grains. The ZHY 1312 OR variety showed the lowest number of grains in row with 34 grains, but for this variety can be declared greatest increase over control variant with 10.81%. In addition to this variety, the number of grains increased in two more cases: ZHY 0874 OV and Astronaut (Table 8). Similar result referred **Mosavifeyzabad et al., (2013**). They confirmed positive effect of Zn fertilizer on number of corn grains in one row. However, based on statistical analysis of the variance, variety has a significant influence and increase in the number of grains in a row within the variant Tecnokel Amino Zn was not statistically confirmed (Table 8).

CONCLUSION

Foliar application of Tecnokel amino Zn had not a significant effect on the increase of quantitative and qualitative parameters of sweet corn, but positively affected total yield, especially in case of SF 681 and Overture variety as well as some quantitative parameters like average weight of maize ear. This parameter showed better results within 3 varieties with increase about 20%. However, the effect on carotenoids and total sugar was negligible. Based on our results, we can conclude that statistically significant changes were indicated especially between different genotypes. Greatest results reached varieties Escalate and Overture. Variety Overture achieved highest total yield 13.14 $t.ha^{-1}$.

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