Theses for doctoral dissertation (PhD)

ASSESSMENT OF ABIOTIC STRESS EFFECTS IN DIFFERENT SWEET CORN GENOTYPES

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1. INTRODUCTION

The cultivation of sweet corn plays a prominent role in Hungary's vegetable growing sector. In terms of production area and production volume, Hungary is the leading producer, together with France in the EU (Lente, 2012).

Thanks to our domestic soil properties, we can claim a favourable position in sweet corn cultivation both in the world and in Europe. Since climate is the primary determinant of agricultural productivity, climate change greatly affects, for example, crop production, the water balance, and other elements of agricultural systems. Understanding, assessing and managing the effects of climate change on production and food supply is a human interest (Adams et al., 1998).

There are many possible ways to adapt to climate and atmospheric changes in agriculture. In the case of crop production systems, one of the most important tasks is to maintain the quality of the crop, for which a solution can be provided, for example, by the use of varieties/species that are characterized by a high germination percentage, have better drought and heat tolerance (Howden et al., 2007), and better tolerate the temporary cold effect

Irrigation also plays an important role in the competitive cultivation of sweet corn in Hungary, as this culture is very sensitive to an even supply of water. However, the quality of irrigation water is not adequate in all growing areas.

Since the demand for Hungarian sweet corn is indisputable, I found it worthwhile to investigate how crop security can be maintained despite weather extremes. In addition, how can areas characterized by less favourable conditions (irrigation water with a high salt content) be brought into production in order to increase the cultivation area.

Objectives of the research

According to my hypothesis regarding the possibility of increasing the ability to adapt to cold stress, the early cultivation technology for the production of the primary commodity base can be made safer by selecting a suitable genotype (more tolerant to cold) and by training the young plants to a suitable extent (training them to lower than optimal temperatures). For investigating the effects of cold stress, I used a climate chamber to simulate the early spring cold and analyzed its effect on the stress tolerance of different genotypes. For this, I growed the seedlings until the age of 5 leaves, at which time the initialization of the ear of corn formation takes place, i.e. the most critical phenophase for the potential development of the generative stage.

According to my second hypothesis regarding the application of irrigation with a water has higher salt content, there may be differences between the individual genotypes in terms of salt tolerance, which can possibly be further enhanced by providing a more favourable soil structure with the use of soil conditioners and soil improvers, allowing harmful salts to wash into deeper layers. In this way, areas characterized by less favourable agroecological conditions can also be brought into production. In my experiments investigating the effects of secondary salinization, in addition to the effects of irrigation with high-salt water on the soil and various sweet corn hybrids, I investigated whether the effects of abiotic stress factors can be mitigated by using different soil conditioners and soil improvers.

The objectives of the research work were the following:

1. Examining different temperature conditions during seedling growth.
2. Evaluation of the stress effect caused by low temperature on the development of the generative stage, photosynthetic activity and yield results in different genotypes.
3. The effect of increased soil salinity on various quantity and quality determining parameters for different sweet corn genotypes.
4. Testing soil improvement products on soil exposed to secondary salinization in small-plot experiments.

2. MATHERIAL AND METHODS

2.1. Description of the cold stress experiment

The experiment aimed to determine the tolerance of various sweet corn hybrids to cold stress was carried out in the Arboretum and Demonstration Garden of Institutes for Agricultural Research and Educational Farm of the University of Debrecen between 2019 and 2022. In the experiment, I used *Gyöngyhajnal*, *Nugat 72, Strongstar,* and *Sweetstar* hybrids. In this experiment, we investigated the responses of the plants to cold stress. Sweet corn seedlings were grown with two different seedling methods (normal and trained) up to the 5-leaf stage of sweet corn seedlings.

During the normal seedling growing method, the seeds were germinated in a closed place at the optimal temperature of 25 °C. After emergence, an average temperature of 20-29 °C was ensured during the further education. The basic idea for the trained seedling cultivation method was given by the fact that the training of young plants during seedling growing has an extremely important role in enhancing the plant's ability to adapt to external environmental factors. Thus, sweet corn seeds were germinated in an air-conditioning cabinet for 14 days in the range of 10-16 °C, and after germination we continued to grow the seedlings under unheated plastic tunnel until planting, which were already exposed to significant cold effects in the initial period.

Methods and measurements in the cold stress experiment

In the research work, we examined the effect of different seedling growing methods on different plant morphological parameters (plant height, number of leaves, mass of above ground biomass, ear length, kernel row numbers) and the yield. In addition, before the harvest, I also monitored the parameters characterizing the photosynthetic activity of the plants (SPAD, NDVI) in all four experimental years. The relative chlorophyll content of the leaves was measured with a SPAD 502 relative chlorophyll content measurer, and a Trimble® GreenSeeker® sensor was used to measure plant biomass and display it as NDVI (Normalized Vegetation Index). Furthermore, in order to determine the extent of the stress effect occurring in the plants, we also examined the proline content of the leaves opposite the ear based on the methodology of Bates (1973).

2.2. Description of the salt stress experiment

The other part of the research is based on the idea that it is worth examining crop production possibilities in areas prone to salinity or salinization (characterized by salt waters), since the sector has to keep up with the rapidly growing population of the Earth. Our experiment was set up based on the results of preliminary research at the Research Institute of Karcag of the Hungarian University of Agriculture and Life Sciences (former Research Institute of Karcag of Institutes for Agricultural Research and Educational Farm of the University of Debrecen). 6 different hybrids (*GSS5649, GSS3071, GSS8529, Sweetstar, Tyson, Overland*) were irrigated with saline water which is typical of the region in 2019. The 4 best-performing hybrids (*GSS3071, GSS8529, Sweetstar, Tyson*) were further investigated (performing a kind of selection) between 2020-2022. In 2019, we examined 2 soil amendments *(Explorer 21, Neosol*), while from 2020, 3 (*Explorer 21, Neosol, Rhyolite tuff*) were involved in the experiments.

Methods and measurements in the salt stress experiment

Every year, a restricted soil test was performed in the Accredited Laboratory of the Research Institute of Karcag. The effect of irrigation with high-salt water on the salt content per layer of 0-60 cm was determined based on the actual salt balance calculation (Rivera Garcia et al., 2021). The moisture content of the 0-40 cm soil layer was measured with the 3T SYSTEM moisture measuring instrument, which records and saves long time series data in v/v% of the open field water capacity in its memory, broken down every 10 cm layers.

The plant tests are the same as the plant tests that determine the morphological properties carried out in the cold stress experiment. In addition, we also examined proline content in the salt stress experiment to quantify the degree of stress effect.

Statistical processing of data

The statistical evaluation of the data from the measurements was carried out with the SPSS 25.0 program package. The statistical reliability of our data was checked by analysis of variance, and the correctness of the differences between the means was checked by Duncan's test.

3. RESULTS

3.1. Results of the cold stress experiment

3.1.1. The effect of cold stress on the SPAD and NDVI values of the examined hybrids

The NDVI and SPAD values measured on plants depend to a large extent on genetic properties, which can be modified by environmental and technological conditions, as well as various stress effects (Lemaire et al., 2008). Based on the SPAD and NDVI measurements, it can be established that the cold stress applied from the beginning of the seedling cultivation, i.e. the training of the seedlings, had a favourable effect in all four experimental years. Among the hybrids used, the *Sweetstar* hybrid showed the most intensive photosynthetic activity based on the SPAD and NDVI values in both years. Looking at the results of the ear weight with husk, it can be concluded that regardless of the training, the hardened seedling cultivation had a favourable effect on this parameter for all genotypes.

3.1.2. The effect of cold stress on the ear weight with husk of the tested hybrids

Based on the **2019** ear weight with husk data, it can be established that in the case of *Nugat 72*, *Strongstar* and *Sweetstar*, we measured a statistically verifiable higher results in individuals from trained seedling method. The *Sweetstar* (311.3 g ear^{-1}) and *Strongstar* (302.7 g ear^{-1}) hybrids were characterized by the highest ear weight with husk. In **2020**, all hybrids with the exception of *Nugat 72* were characterized by a higher ear weight with husk in the individuals from trained seedling method.

However, significant differences were only detected in the case of *Gyöngyhajnal* (288.8 g ear^{-1}) and *Sweetstar* (370.1 g ear^{-1}) genotypes. This year, we measured the largest ear weight with husk in the case of the trained *Sweetstar* hybrid. In **2021**, with the exception of the *Strongstar* hybrid, the ear weight with husk of all genotypes was greater as a result of training. In the 3rd year of the research work, the highest weight of the ear weight with husk was achieved by the trained *Sweetstar* hybrid (394.7 g ear^{-1}). In **2022**, the 4th year of the research work, the genotypes that benefited from trained seedling cultivation could be characterized by a significantly higher ear weight with husk, of which the *Sweetstar* hybrid stood out with an average ear weight with husk of 372.5 g.

3.1.3. The effect of cold stress on the ear weight without husk of the examined hybrids

In **2019**, we were able to show a statistically verifiable increase in the weight of the ear without husk in favour of the trained *Sweetstar* hybrid (226.9 g ear^{-1}). The trained *Strongstar* hybrid was characterized by the second largest ear mass without a husk (215.3 g ear^{-1}), but this result was not significant compared to normal seedling growing method, as was the case with the *Nugat 72* and *Gyöngyhajnal* genotypes. In the second year of the research work (**2020**), the trained *Strongstar* hybrid grew the largest ear weight without husk (244.4 g ear^{-1}) for normal seedling growing method. The second largest ear weight without husk was measured in the case of the trained *Sweetstar* (243.7 g ear^{-1}), however, the value did not provide a significant difference for the *Sweetstar* hybrid that received normal seedling growing method (233.9 g ear^{-1}). In the case of the *Nugat 72* genotype, there was no statistically verifiable difference between the two methods of growing seedlings, however, the trained *Gyöngyhajnal* was characterized by a significantly better ear mass without husk (215 g ear^{-1}). In **2021**, the trained *Sweetstar* (256.2 g ear^{-1}) and the trained *Strongstar* (243.7 g ear^{-1}) hybrids could be characterized by a statistically verifiable higher ear weight without husk. In addition, the trained *Gyöngyhajnal* (213.1 g ear^{-1}) and the trained *Nugat 72* (211.5 g ear^{-1}) genotypes grew significantly larger ear mass without husk compared to individuals with normal seedling growing method. In **2022**, with the exception of *Nugat 72*, we measured significantly higher ear weight results without husk for the genotypes with trained seedlings. The trained *Sweetstar* hybrid was characterized by the highest ear weight without husk (261.2 g ear^{-1}), which was statistically greater than the trained *Strongstar* hybrid (240.9 g ear^{-1}).

3.1.4. The effect of cold stress on the kernel row number of the tested hybrids

In the first year of the research work (**2019**), we could not show statistically verifiable differences in the number of kernel rows in favour of any seedling growing method, and in addition, there were no significant differences between the applied genotypes either. In **2020**, we measured more favourable eye number values compared to the kernel row number values that occurred as a result of the drastic cold stress that occurred in the first year. The best kernel row number was characterized by the trained *Gyöngyhajnal* (15.6 pieces ear^{-1}) and the *Sweetstar* (15.1 pieces ear^{-1}), however, this value was significantly higher only in the case of *Sweetstar* than that of the normal seedling growing method.

In 2021, there were no significant differences either in the case of the seedling growing method or between the individual genotypes. Nevertheless, we measured more favourable kernel row number values for all 4 genotypes (*Gyöngyhajnal*: +1.1 pieces ear^{-1}; *Nugat 72*: +0.7 pieces ear^{-1}; *Strongstar*: +0.9 pieces ear^{-1}; *Sweetstar*: +0.6 pieces ear^{-1}). Based on the kernel row number results measured in **2022**, it can be established that in the case of all four tested genotypes, the kernel row numbers of each individual were characterized by more kernel row numbers on average (*Göngyhajnal*: +0.5 pieces ear^{-1}; *Nugat 72*: +1.2 pieces ear^{-1}; *Strongstar*: 1, 4 pieces ear^{-1}; *Sweetstar*: 0.5 pieces ear^{-1}), however, these excesses cannot be statistically verified in 5% of significance level.

3.1.5. The effect of cold stress on the ear length of the investigated hybrids

In **2019**, among the different seedling growing methods, the ear length of the trained seedlings was longer for *Nugat 72* (18.7 cm), *Strongstar* (19.2 cm) and *Sweetstar* (19.5 cm) than those with normal seedling growing method. The ear length of these hybrids was minimally below their genetic characteristics, despite the fact that they suffered from cold stress not only during seedling growing period, but also after the seedlings were planted. In **2020**, there was a statistically verifiable difference in tube length in favour of *Gyöngyhajnal* with trained seedlings (+1.2 cm). In the case of the other three hybrids, in a statistical sense, the two different ways of growing seedlings did not result in a difference in ear length. An important result is that the different hybrids still approached their characteristic, genetically coded ear length as a result of the drastic training during the seedling stage. In **2021**, individuals from trained seedling growing also grew longer ears, of which *Strongstar* (20.6 cm) and *Sweetstar* (20.4 cm) stood out. However, these differences cannot be verified statistically in the case of any genotype compared to the stock with normal seedling growing method. As a result of training, *Strongstar* came closest to the ear length coded in its genetic characteristics, and the trained *Sweetstar* exceeded it by 1.4 cm. Based on the ear length data measured in the last year of the study period (**2022**), it can be established that the individual hybrids produced significantly longer ears as a result of the trained seedling growing (*Göngyhajnal*: +2.9 cm; *Nugat 72*: +2.0 cm; *Strongstar*: +2.1 cm; *Sweetstar*: +1.2 cm). In terms of ear length, only the *Gyöngyhajnal* hybrid did not reach the average ear length of 19.6 cm in the variety description under the influence of any seedling growing method.

3.1.6. The effect of cold stress on the proline content of the investigated hybrids

In the initial year of the research work (**2019**), the proline content of the trained seedlings was lower compared to the values measured in the normal seedling growing plants for all four genotypes, however, these differences cannot be verified at a 5% significance level. The *Sweetstar* hybrid showed the lowest proline content, which indicates a more favourable cold stress tolerance. This fact is also proven by the fact that the trained *Sweetstar* hybrid achieved statistically verifiable better results for most of the parameters presented in the previous subsections. In **2020**, we can make the same statement regarding the proline content as in the initial year of the experiment. Genotypes with normal seedling growth accumulated more proline, which suggests that they are less stress-tolerant than genotypes with less proline accumulated, with trained seedling growth, however, these differences cannot be verified statistically. The least proline-accumulating hybrid this year was also *Sweetstar* in terms of both seedling cultivation methods. In **2021**, we can also make the same statement as in the previous two test years regarding the seedling growing method and the proline production of the individual genotypes, however, at a 5% significance level, these results cannot be verified statistically either. In the last year (**2022)** of the research work, we also measured a lower proline content for all genotypes with trained seedlings. The hybrid characterized by the lowest proline content, i.e. the highest stress tolerance in terms of proline production, was also *Sweetstar* in 2022, however, due to the standard deviation values, this result cannot be considered significant either ($p \leq 0.05$).

3.2. Results of the salt stress experiment

3.2.1. The effect of irrigation with saline water on the salt mass of the 0-60 cm of the soil

At the beginning of the salt stress experiment (**2020**), based on the diagram (*Figure 1*) showing the total soluble salt content of the soil samples taken from the 0-60 cm layers (before the application of soil conditioners), it can be established that the individual layers contained almost the same amount of total soluble salt at the beginning of the experiment in all 4 experimental plots.

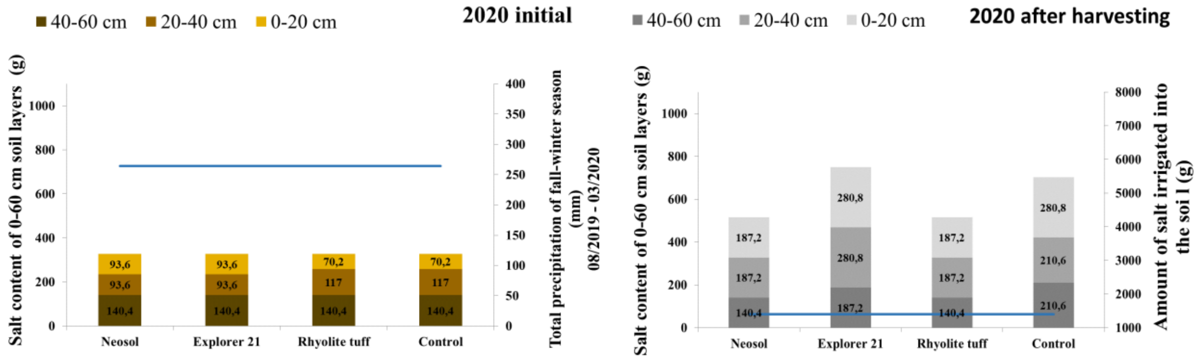

Figure 1: Changes in the salt mass of the 0-60 cm layers of soils treated with different soil improvement materials in the 2020 test year

The lowest amount of salt was always measured in the upper 0-20 cm layers (*Neosol*, *Explorer* 21: 93.6 g; *Rhyolite tuff*, control: 70.2 g), and the highest amount of salt was always measured in the lower, 40-60 cm and layers, an uniform amount of 140.6 g. In the period between August 2019 and March 2020, a total of 264 mm of precipitation fell based on the data of the meteorological station located on the territory of the Research Institute of Karcag. Based on the measurements of the soil samples taken after harvesting, it can be established that the salt mass in the 0-60 cm layers was the least affected by the soil improvement products *Neosol* and Rhyolite tuff (514.8 g). Most of the harmful salts (374.4 g) were still detectable in the upper 40 cm layer, from the soil samples taken immediately after harvesting, in the case of both plots treated with soil conditioners. During the measurement of the soil samples of the *Explorer 21* and control treatments, which mainly promote root growth, compared to the previous two treatments, we found a larger salt mass per layer (*Explorer 21*: 748.8 g; control: 702 g) in the 0-60 cm layers. Similar to the other two treatments, in these plots, even in the upper 0-40 cm layers, the greater part of the harmful salts applied by irrigation was found (*Explorer 21*: 561.6 g; control: 491.4 g). Based on the results, it can be concluded that the use of *Neosol* and Rhyolite tuff had a positive effect on the soil structure, so that the salts causing secondary salinization were able to wash in the deeper layers outside the root zone, thereby reducing the effect of inhibiting water and nutrient absorption.

Based on the diagram (*Figure 2*) containing measurements of soil samples taken in April of the second year of the study period (**2021**), it can be seen that the natural precipitation amount in the fall and winter of the period 2020-2021 was 355.2 mm (91.2 mm more than the previous year).

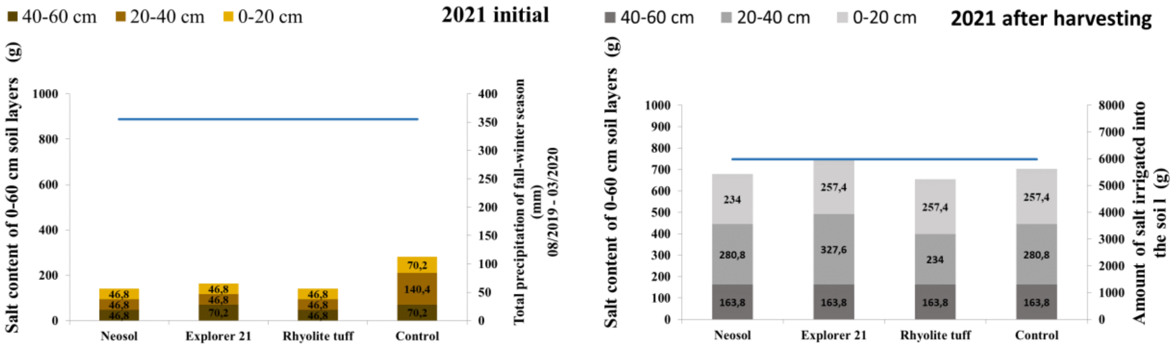

Figure 2: Changes in the salt mass of the 0-60 cm layers of soils treated with different soil improvement materials in the 2021 test year

This extra amount of precipitation contributed to starting another year of the salt stress experiment with a much lower amount of salt in the second year of the research work. This statement is true for all plots, however, the most outstanding results were shown in the plots treated with *Neosol* and Rhyolite tuff, which also had a positive effect the previous year. Thanks to the *Neosol* and Rhyolite tuff treatments, we started the second year of the research work with a salt supply of 140.4 g in the 0-60 cm layer (which was 187.2 g less thanks to the larger amount of autumn rain that fell in the 2020-21 period -winter precipitation). In contrast, the salt content of the soils of the plots treated with *Explorer 21* was 163.8 g, while the salt mass of the control plots was 280.8 g in the 0-60 cm layer. Based on the measurements of soil samples taken after harvest, it can be concluded that in this study year as well, the amount of salt in the 0-60 cm layer was the least due to the effects of the soil improvement products *Neosol* (678.6 g) and Rhyolite tuff (655.2 g). The salt content of the soil samples of the *Explorer 21* treatment was 748.8 g, while that of the control plots was 702 g in the 0-60 cm layers. Based on the results, it can be concluded that the use of *Neosol* and Rhyolite tuff also had a positive effect on the soil structure in the second year of the experiment, so despite the significantly higher salt load (+ 4579.3 g) compared to the previous year, they were able to wash into the deeper layers salts causing secondary salinization.

Based on the diagram (*Figure 3*) showing the salt content of the soil samples taken in the period before the application of fertilizers and soil improvers in the last year of the research work (2022), it can be observed that the autumn-winter natural precipitation of the period 2021-2022 was 177.7 mm (177.5 mm less than the previous year).

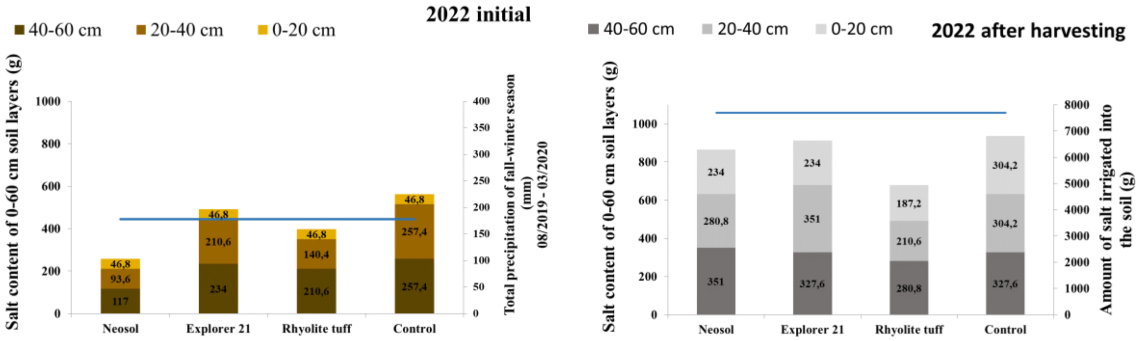

Figure 3: Changes in the salt mass of the 0-60 cm layers of soils treated with different soil improvement materials in the 2022 test year

Since half as much precipitation fell in the autumn-winter period compared to the previous period, the rate of leaching of harmful salts accumulated in the 2021 growing season was also lower. The effect of the multi-year application of *Neosol* treatment, which was characterized by favourable results in previous years, can be said to maintain a more favourable soil structure to facilitate the leaching of harmful salts, even after the autumn-winter period with less precipitation, because in 2022 the initial salt content in the 0-60 cm layer was 257.4 g. In the case of the *Rhyolite tuff* treatment, which also performed well in 2020-2021, we were able to start the 2020 growing season with a salt supply of 397.8 g, which was 139.4 g more than the *Neosol* treatment, which proved to be the most favourable. Based on the figure, however, it can be observed that more than half (52%) of this salt mass is found in the 40-60 cm layer, so as a result of the multi-year treatment, the movement of harmful salts towards deeper layers, i.e. washing out, can be observed in the significantly less autumn despite the amount of winter precipitation. The salt pool of the 0-60 cm layer of the plots treated with *Explorer 21* started from 491.4 g, while that of the control plots started from 561.6 g in the last study year, which resulted in a significant salt load already at the beginning of the last growing season. Based on the measurements of the soil samples taken after harvesting, it can be established that the salt mass of the 0-60 cm layer was the least due to the effect of the *Rhyolite tuff* (678.6 g) soil improvement product. This amount was almost the same as the salt stock determined after the harvest of 2021 (2021: 655.2 g), despite the fact that we applied 1716.2 g more salt due to the drier vintage with the greater number of irrigations. The salt content of the soil samples of the *Neosol* treatment (865.8 g in total) clearly started to wash into the deeper layers (0-20 cm: 234 g; 20-40 cm: 280.8 g; 40-60 cm: 351 g) characterized by less natural precipitation despite the vintage, however, this leaching was slower than in the case of *Rhyolite tuff*. In the last study year, the most salt-laden environment occurred in the *Explorer 21* treatment (912.6 g) and the control plots (936 g) in the examined soil layer.

3.2.2. The effect of soil improvements on soil moisture content

Already in the first year (**2020**) of the use of the soil improver materials included in the experiment, the *Rhyolite tuff* treatment stood out, as it showed the smallest fluctuation in the moisture content of the soil layer most exposed to drying (0-10 cm) (the largest decrease: 50 mm). With the use of *Rhyolite tuff*, the moisture content of the 0-40 cm layer of the tested plots was 100 mm after harvesting. In addition, the application of *Neosol* also had a positive effect on the moisture conservation of the upper soil layer of each plot, because after harvesting (08/04/2020) the moisture reserve of the 0-40 cm layer was around 110 mm for both treatments.

The soil improver products included in the experiment in order to study the cumulative effect that can be derived from their multi-year use, we also monitored the changes in the 0-40 cm moisture content measured in the last year (**2022**) of the study period. The year 2022 resulted in extremely dry conditions, as 150 mm less precipitation fell compared to the 50-year average. Even in the low-rainfall period of 2022, the use of *Rhyolite tuff* proved to be the most favourable in terms of the effect on moisture content, since the largest moisture reserve was able to be preserved at the end of the growing season with this treatment, with the moisture content of the upper layers also balanced (greatest moisture loss: 60 mm), so even as a result of the long-lasting drought, the upper layers did not dry out significantly.

3.3. The effect of salt stress and soil improvers on the quantitative and qualitative indicators of the investigated hybrids

3.3.1. Ear weight with husk

In the case of the ***GSS3071*** hybrid, in the 2020 and 2021 test years, no statistically verifiable differences could be detected for any of the treatments. In 2020, the *Explorer 21* (368.2 g ear^{-1}) treatment was characterized by the highest ear weight with husk, and in 2021, the *Neosol* (364.8 g ear^{-1}) and *Rhyolite tuff* (364.6 g ear^{-1}) treatments were characterized by almost identical values. In 2022, there was a statistically verifiable difference in the average ear weight with husk of hybrids treated with *Explorer 21* (410.9 g ear^{-1}) and Rhyolite tuff (414.6 g ear^{-1}).

In the case of the ***Tyson*** hybrid, the ear weight with husk of all three treatments was statistically verifiably greater than that of the individuals of the control plots. The best results were measured in individuals treated with *Explorer 21* (433.9 g ear^{-1}) in 2020 and *Neosol* (376.4 g ear^{-1}) in 2021. Based on the statistically verifiable reductions in the 3-year-old ear weight results of the *Tyson* hybrid, it can be concluded that it can be considered a salt-sensitive hybrid, since it reacted to the amount of salt introduced and accumulated in the soil over the years with a decrease in crop size. Compared to the results of the ear weight with husk in the initial period, the smallest decrease in crop size was experienced as a result of the treatments that help wash out the accumulated salt amount, i.e. *Neosol* (-174.2 g ear^{-1}) and *Rhyolite tuff* (-184.6 g ear^{-1}). This reduction was -248.6 g ear^{-1} in the case of the *Explorer 21* treatment, and -237.6 g ear^{-1} in the case of the control.

Based on the results of the ***Sweetstar*** hybrid ear weight with husk, it can be concluded that in the first year of the experiment, the samples from the Rhyolite tuff treatment were characterized by a statistically verifiable higher ear weight (424.2 g ear^{-1}). As a result of the significantly higher salt input (+ 4579.3 g) compared to the initial year, a decrease was observed in the 2021 ear weights, however, based on the figure, the *Rhyolite tuff* treatment proved to be the best even this year (361.4 g ear^{-1}). By the third year of the study period, the reduction continued to increase for all treatments. No statistically verifiable differences can be detected between the individual soil conditioners, however, each of them resulted in a statistically verifiable greater mass of ear with husk compared to the control individuals.

There was a statistically verifiable difference in the development of the ear weight with husk of the hybrid ***GSS8529*** in favour of all three soil improvement preparations compared to the control in the period 2020-2021, however, there was no statistically verifiable difference between the individual preparations. In 2022, the favourable effect was also statistically confirmed for individuals treated with soil improvement preparations compared to the control. The best results in all three experimental years were demonstrated for the *Rhyolite tuff* treatment (2020: 393.7 g ear^{-1}; 2021: 427.2 g ear^{-1}; 2022: 354.2 g ear^{-1}). In the case of the *GSS8529* hybrid, it can also be verified that, compared to the initial period, the weight of the ear with husk decreased in the last year of the experiment. Nevertheless, this decrease was smaller in the case of the *Neosol* (-24 g ear^{-1}) and Rhyolite tuff (-39.5 g ear^{-1}) treatments, which promote the leaching of the amount of salt applied with irrigation water.

3.3.2. Ear weight without husk

In the case of the ***GSS3071*** hybrid, in the first year of the experiment, no statistically verifiable difference could be detected in favour of any of the treatments in the weight of the ear without the cover leaves, which was below the export minimum requirement. In 2021, the *Rhyolite tuff* treatment (288 g ear^{-1}) emerged with the most favourable average ear weight without husk, statistically verifiable at a 5% significance level. Thanks to the use of soil-improving materials, in the last year of the research work, a significant increase in the ear weight without leaves was detected, which was statistically verifiable in the case of all three materials compared to the control and the yield results of previous years. The best weight of the ear without husk was characterized by *Rhyolite tuff* (323.6 g ear^{-1}) and *Explorer 21* (304.5 g ear^{-1}). This means a higher value category, so it can be concluded that thanks to these materials for soil improvement, class I. export raw material can be produced despite significant salt stress. By using the *Neosol*, the average weight of ear without husk can also be improved, since while in the case of the control the average ear weight without husk was below the minimum requirement, with the use of *Neosol*, even in the most salt-laden and at the same time least-precipitated year (2022), it was above the minimum requirement (279.9 g ear^{-1}) average was detectable.

In the case of ***Tyson*** hybrid, in the initial year of the research work, a statistically verifiable difference in favour of the *Neosol* (308.4 g ear^{-1}) and *Rhyolite tuff* (307.2 g ear^{-1}) treatments was found when examining the weight of the ear without husk, which results also meet the minimum requirement of the higher value category. Compared to the period of 2020, in the year characterized by less natural precipitation, and therefore more significant salt stress due to irrigation, there is already a decline in the results of deprived pipe mass. Despite this, the average ear weight without cover leaves of the individuals of the plots treated with soil improvers (*Neosol*: 247.1 g ear^{-1}; *Explorer 21*: 258.6 g ear^{-1}; *Rhyolite tuff*: 247.0 g ear^{-1}) was statistically verifiably more favourable than the control (208.5 g ear^{-1}), in which case we measured values well below the minimum requirements. In the last year of the salt stress experiment, a drastic decrease was observed in the results of stripped pipe mass.

However, in the year characterized by the lowest amount of natural precipitation and thus exposed to the greatest salt stress, the soil improvement also showed more favourable results (*Neosol*: 175 g ear^{-1}; *Explorer 21*: 105.7 g ear^{-1}; *Rhyolite tuff:* 167.4 g ear^{-1}) compared to the control (70.1 g ear^{-1}), however, these results did not meet the minimum requirements. The sensitivity of the *Tyson* hybrid to salt stress was confirmed in this parameter as well.

In the ***Sweetstar*** hybrid, in the first year of the experiment, only in the case of the *Rhyolite tuff* (261.6 g ear^{-1}) treatment, there was a statistically verifiable difference in the ear weight without cover leaves compared to the control, which also met the minimum export requirements. As a result of the *Explorer 21* treatment, the average weight of the ear without cover leaves was 248.9 g ear^{-1}, while the *Neosol* treatment was 241.1 g ear^{-1}, while in the case of the control this value was 230.4 g ear^{-1}. The *Sweetstar* hybrid also showed a negative response to salt stress, as a decrease in the ear weight without husk was also observed in the more salt-laden years (2021-2022). However, with the use of soil improvement products, statistically verifiable results were more favourable (except for *Neosol* treatment in 2021) compared to the results of the untreated plots.

In the case of the ***GSS8529*** hybrid in the 2020 test year, at a significance level of 5%, we measured more favourable values for the weight of the ear without husk as a result of the soil improvement treatments (*Neosol*: 267.0 g ear^{-1}; *Explorer 21*: 280 g ear^{-1}; *Rhyolite tuff*: 265 g ear^{-1}) compared to the control (221.5 g ear^{-1}). However, there were no statistically verifiable differences between the individual treatments in a year where, as a result of more favourable natural precipitation, less irrigation water was applied. 2021 was characterized by less natural precipitation (98.4 mm), so a total of 150.1 mm of irrigation water was applied, which was 4579.3 g more salt input compared to the previous year. Nevertheless, in the case of the *GSS8529* hybrid, the ear weight without husk values were statistically verifiably better compared to the results of the treated plots in 2020 and the control results of the 2020-2021 period. The highest value (323.7 g ear^{-1}) was measured using the *Rhyolite tuff* treatment, which significantly exceeded the minimum requirement of the higher value category. In the last year of the salt stress experiment, compared to the salt input in 2021, the more intensive irrigation (+118.6 mm) required due to the drought year resulted in a salt input higher by +1716.2 g. Thus, in the case of the *GSS8529* hybrid in 2022, the results of the weight of ear without husk also decreased compared to the previous (less salt-laden) years. As a result of the soil improvement treatments, these stripped tube weight results can be statistically proven to be more favourable (*Neosol*: 217.2 g ear^{-1}); *Explorer 21*: 199.8 g ear^{-1}; *Rhyolite tuff*: 261.2 g ear^{-1}) proved to be better than those who did not receive the treatment (control: 170.8 g ear^{-1}). Among the treatments with soil improvers, there was a statistically verifiable surplus in favour of the *Rhyolite tuff* treatment. In the case of the *GSS8529* hybrid, we experienced a negative response in the case of the *GSS8529* hybrid in the same way as in the case of the bare ear weight results, as a result of irrigation with salt-laden irrigation water for several years, but this negative effect can be clearly reduced by the use of soil improvement preparations.

3.3.3. Ear length

For the ***GSS3071*** hybrid in 2020, the average ear length for all treatments was around 20 cm, as defined in the variety description. The longest ears were measured as a result of the *Explorer 21* treatment (21.2 cm), however, this excess could not be statistically verified compared to the other treatments or the control. In 2021, the year characterized by less salt input, the change was + 0.2 cm for the *Neosol* treatment, - 0.6 cm for the *Explorer 21* treatment, - 0.3 cm for *Rhyolite tuff*, and - 0.5 cm for the control, which in neither case were they found to be significant. Even under the more drastic salt stress, we did not experience a significant decrease in ear length in any of the stocks. Although it cannot be verified statistically, in 2022 the ears (21.2 cm) improved the most as a result of the *Explorer 21* treatment.

Based on the examination of the ear length of the ***Tyson*** hybrid, it can be concluded that at the beginning of the experiment, all treatments were characterized by the values of around 20 cm in the variety description, and there were no statistically verifiable differences between them. The *Explorer 21* treatment resulted in the most favourable ear length of 20.6 cm. In 2021, compared to the previous year, the higher salt input negatively affected the ear length (*Neosol*: - 0.3 cm; *Explorer 21*: - 0.8 cm; *Rhyolite tuff*: - 0.8 cm; control: -1.3 cm). There was no significant difference between the individual treatments. The ear length of the *Tyson* hybrid, which proved to be more sensitive to salt in several aspects, was statistically verifiable in the last year of the test period compared to the values measured in the initial period. *Neosol*: - 5.3 cm; *Explorer 21*: - 8.9 cm; *Rhyolite tuff*: - 5.1 cm; control: - 8.7 cm. As a result of the *Neosol* and *Rhyolite tuff* treatments, this adverse effect was statistically verifiable to a lesser extent.

In the case of the ***Sweetstar*** hybrid in 2020, there was no significant difference in favour of either treatment in terms of ear length. In all cases, average values above 21 cm were measured, which exceeds the genetically coded trait (20 cm) specified in the breed description. In the year 2021, a negative change occurred only in individuals of the control plots (- 0.4 cm). As a result of the *Explorer 21* treatment, we measured statistically verifiable longer ears compared to the 2020 data (+ 1.4 cm). In the case of the *Sweetstar* hybrid, which also proved to be more sensitive to salt in terms of several parameters, smaller ears were formed in 2022 compared to the initial period (in a salt-poor environment) (*Neosol*: - 1.1 cm;

Explorer 21: - 1.1 cm; *Rhyolite tuff*: - 1.5 cm; control: -1.7 cm). These differences are significant compared to 2020 (with the exception of the *Neosol* treatment).

In 2020, the ear length of the hybrid ***GSS8529*** was well above the average 20 cm specified in the variety description (*Neosol*: 22.1 cm; *Explorer 21*: 22.7 cm; *Rhyolite tuff*: 22 cm; control: 21.6 cm). In 2021, despite the higher salt input, we did not experience a negative change in the ear length compared to the previous year's results (*Neosol*: + 0.1 cm; *Explorer 21*: + 1.6 cm; *Rhyolite tuff*: + 1.1 cm; control: - 0.1 cm), however, these changes are not significant in either case. In the year 2022, thanks to the more drastic salt input, a negative effect was detected in the ear length compared to the initial period (*Neosol*: -1.1 cm; *Explorer 21*: - 0.9 cm; *Rhyolite tuff*: - 0.2 cm; control: - 5, 2 cm). However, thanks to the applied soil improvement materials, this reduction was only small, but in the case of the control, it resulted in a significant, statistically verifiable reduction in the ear length. In the case of the *GSS8529* hybrid, the significantly best result among the treatments was measured under the influence of the *Rhyolite tuff* treatment (21.8 cm).

3.3.4. Kernel row number

In the case of the ***GSS3071*** hybrid, it can be established that the average kernel row number values were the most favourable in the least salt-stressed year, i.e. 2020, which exceeded the upper limit of 16 in the variety description for all treatments. It cannot be verified statistically, but the *Explorer 21* (17.6 pcs) and *Rhyolite tuff* (17.4 pcs) treatments showed more favourable values. As a result of the moderately salt-laden period, the average grain row number decreased in all cases (*Neosol*: - 0.7 pcs; *Explorer 21*: - 0.8 pcs; *Rhyolite tuff*: - 1.5 pcs; control: - 1.9 pcs), however, the soil conditioner treatments, this value was not significantly, but better than the control. However, in the year with the most salt input, the positive effect of the soil improvement products on kernel row number compared to the control could also be verified statistically, of which the *Rhyolite tuff* treatment proved to be the most favourable (16.3 pcs).

Based on the results of the grain number measured during the examination of the ***Tyson*** hybrid, it can be established that in 2020 the samples from all treatments showed the lowest value of the average kernel row number typical of the breed (*Neosol*: 19.8 pcs.; *Explorer 21*: 20.8 pcs.; *Rhyolite tuff*: 20.0 pcs; control: 20.1 pcs), between which there was no significant difference. As a result of the moderately salt-laden season of 2021, the average number of kernel rows decreased significantly and statistically clearly in all cases (*Neosol*: -2.2 pcs; *Explorer 21*: -2.9 pcs; *Ryholite tuff*: -1.6 pcs; control: -2 .0 pcs), however, as a result of the *Rhyolite tuff* treatment, this value, although not significantly, was better than the control. In the year 2022, which was the most salt-laden year, a further decrease was observed during the examination of the number of kernels in the case of the hybrid, which was also considered very salt-sensitive in the previous quality parameters. Compared to the control, the more positive effect of the soil improvement preparations on the reduction of kernel rows was clearly significant, of which the *Rhyolite tuff* (16.3 pcs) and *Explorer 21* (16.2 pcs) treatments proved to be more favourable. However, these values are already significantly lower than the eye row number values produced under normal conditions in the breed description.

Based on the results of the ***Sweetstar*** hybrid in 2020, the kernel row number of 16 for the variety was typical, regardless of the treatment received by each plot (*Neosol*: 16.7 pcs; *Explorer 21*: 16.5 pcs; *Rhyolite tuff* 16, 5 pcs; control: 15.9 pcs). No significant differences could be detected either in the effect of individual preparations or in the effect of soil improvement. In the 2021 test year, even for the hybrid, which is considered more salt-sensitive based on the previous parameters, there was a decrease in the average kernel row number (*Neosol*: - 1.8 pcs.; *Explorer 21*: - 1.0 pcs.; *Rhyolite tuff*: - 1.2 pcs.; control: - 1.7 pcs). Despite the fact that the last year of the test period proved to be the most salt-stressed for each hybrid, the *Sweetstar* hybrid did not have the same decline as the *Tyson* hybrid, but the soil conditioners did not have a statistically verifiable effect on the decrease in the number of kernels.

In the case of the ***GSS8529*** hybrid, it can be established that the average kernel row number values were the most favourable in the least salt-stressed year, i.e. 2020, which varied within the range of values specified in the variety description (18-20 pcs) for all treatments. Compared to the control, the *Explorer 21* (19.5 pc) treatment showed statistically verifiable more favourable values. As a result of the moderately salt-laden year, the average number of kernel rows changed minimally in all cases (*Neosol*: - 0.1 pcs; *Explorer 21*: - 0.2 pcs; *Rhyolite tuff*: + 0.6 pcs; control: - 0.4 pcs). As a result of the treatments with soil improvers, these values were not significantly better than those of the control. However, in the most salt-laden last experimental year, the positive effect of the soil improvement preparations on kernel row number compared to the control could be verified statistically, of which the *Rhyolite tuff* (17.4 pcs) and *Explorer 21* (17.3 pcs) treatments proved to be the most favourable.

3.3.5. The yield of sweet corn

Figure 4 shows the effect of each treatment on the sweet corn yield average in the 2020-2022 study period, which was also compared with the national average yield results.

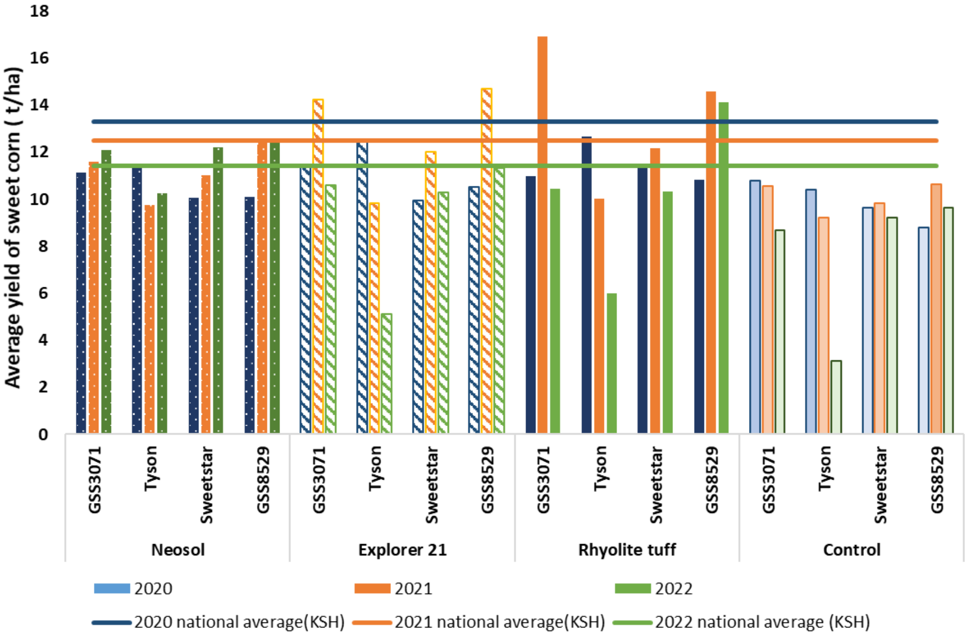

Figure 4: Average yield results based on the different treatments (2020-2022)

In the growing season of **2020** (indicated with blue colors), the national average yield was 13.3 t ha^{-1} in sweet corn growing areas. In the first year of using the soil improvers, regardless of the hybrid, none of the treatments managed to reach the national yield average. *Tyson* was the most outstanding of the hybrids this year in terms of yield average. *Tyson's* average yield was 11.5 t ha^{-1} in the *Neosol* treatment, 12.5 t ha^{-1} in the case of *Explorer 21*, 12.7 t ha^{-1} in the *Rhyolite tuff* treatment, and 10.4 t ha^{-1} in the control. The yield averages of *GSS3071* were as follows: *Neosol*: 11.1 t ha^{-1}; *Explorer 21*: 11.4 t ha^{-1}; *Rhyolite tuff* 11.0 t ha^{-1}; control: 10.8 t ha^{-1}. The average yield of *Sweetar* as a result of *Neosol* treatment is 10.1 t ha^{-1}; 9.9 t ha^{-}

^{1} for *Explorer 21*; 11.5 t ha^{-1} due to *Rhyolite tuff*; and in the case of control it was 9.6 t ha^{-1}. In the case of *GSS8529*, this value is 10.1 t ha^{-1} on plots treated with *Neosol*; It was 10.5 t ha^{-1} under the *Explorer 21* treatment, 10.8 t ha^{-1} in the case of *Rhyolite tuff*, and 8.8 t ha^{-1} in the control.

In **2021** (indicated in orange colors), the national sweet corn yield average was 12.5 t ha^{-1}. This value was exceeded or approached in the case of two hybrids, *GSS3071* and *GSS8529*, thanks to the treatments with soil improvers. The average yield of the hybrid *GSS3071* was 11.6 t ha^{-1} in the *Neosol* treatment, 14.2 t ha^{-1} in the *Explorer 21* treatment, 16.9 t ha^{-1} in the *Rhyolite tuff* treatment, and 10.6 t ha^{-1} in the control. The yield averages of *GSS8529* were as follows: *Neosol*: 12.4 t ha^{-1}; *Explorer 21*: 14.7 t ha^{-1}; *Rhyolite tuff* 14.6 t ha^{-1}; control: 10.6 t ha^{-1}. The average yield of *Sweetar* as a result of *Neosol* treatment is 11.0 t ha^{-1}; *Explorer 21*: 12.2 t ha^{-1} due to *Rhyolite tuff*; and in the case of control it was 9.8 t ha^{-1}. In the case of *Tyson*, this value is 9.7 t ha^{-1} on plots treated with *Neosol*; As a result of the *Explorer 21* treatment, it was 9.8 t ha^{-1}, in the case of *Rhyolite tuff* it was 10.0 t ha^{-1}, while in the control it was 9.2 t ha^{-1}.

In the year **2022** (indicated in green), the national average yield was 11.4 t ha^{-1}, according to data from the Central Statistical Office. This year, the *GSS8529* hybrid also gave an outstanding performance, which was exceeded by the use of *Neosol* (12.6 t ha^{-1}) and *Rhyolite tuff* (14.1 t ha^{-1}) soil improvers, while the *Explorer 21* treatment (11.3 t ha^{-1} ha) reached the national yield average despite the greatest salt stress due to the drought year. The average yield of the *GSS3071* hybrid exceeded the national average due to the *Neosol* treatment (12.1 t ha^{-1}). The average yield was 10.6 t ha^{-1} under the *Explorer 21* treatment, 10.4 t ha^{-1} under the *Rhyolite tuff* treatment, and 8.7 t ha^{-1} in the control. *Sweetstar* performed the best under the *Neosol* treatment with an average yield of 12.2 t ha^{-1}. As a result of the *Explorer 21* and *Rhyolite tuff* treatments, the average yield was 10.3 t ha^{-1}, which is not significantly lower than the national average, compared to the control (9.2 t ha^{-1}). The *Tyson* hybrid, which proved to be salt-sensitive in many ways, was the largest under the *Neosol* treatment (10.3 t ha^{-1}). The average yield was 5.1 t ha^{-1} for *Explorer 21*, 6.0 t ha^{-1} for the *Rhyolite tuff* treatment, and 3.1 t ha^{-1} for the control.

3.3.6. Proline content

In **2020**, i.e. the initial year of the experiment, the *Tyson* hybrid produced the most proline for each treatment (*Neosol*: 9.9 µmol g^{-1}; *Explorer 21*: 10.3 µmol g^{-1}; *Rhyolite tuff*: 10.0 µmol g^{-1}; control: 10.5 µmol g^{-1}). *Tyson* was followed by the *GSS3071* hybrid in terms of proline production, in which case the lowest proline accumulation was observed in the *Neosol* treatment at 87.6 µmol g^{-1}. Overall, the *Sweetstar* hybrid was characterized by the lowest proline content, and in this case the lowest proline content (5.1 µmol g^{-1}) was detected in the leaf samples as a result of the *Explorer 21* treatment. Based on the samples of the *GSS8529* hybrid, the lowest plant stress hormone content was measured in response to the *Neosol* (6.6 µmol g^{-1}) and *Rhyolite tuff (*6.7 µmol g^{-1}) treatments). However, these differences could not be verified at the 5% significance level.

In **2021**, the second year of the research work, despite the fact that we induced a higher salt load for the sweet corn stock, a smaller amount of proline production was detected for each treatment than in 2020. The highest amount of proline content was measured in the case of the *Sweetstar* hybrid grown on the control plot (3.3 µmol g^{-1}). In the case of the *Sweetstar* hybrid, only treatment with the soil conditioning agent *Explorer 21* resulted in a statistically verifiable lower accumulation of proline (1.5 µmol g^{-1}). The second highest proline content was measured in the *Tyson* hybrid of the control plot (3.1 µmol g^{-1}). *Tyson* had lower proline accumulation for each soil amendment treatment (*Neosol*: 2.1 µmol g^{-1}; *Explorer 21*: 2.1 µmol g^{-1}; *Rhyolite tuff*: 2.7 µmol g^{-1}), but these differences were not significant. The smallest proline accumulation in the samples from the control plots was measured for *GSS3071* (1.7 µmol g-1). We measured proline content (1.3 µmol g^{-1}) in *GSS3071* individuals of the plots treated with *Explorer 21* and *Rhyolite tuff*, but this difference could not be statistically verified. In the case of the *GSS8529* hybrid, the average proline content of the samples from the control plot was 2.9 µmol g^{-1}, which was not statistically different from the results of the *Tyson* and *Sweetstar* hybrids, and we could not detect a significantly lower proline accumulation due to soil improvement either.

By **2022**, the *Tyson* and *Sweetstar* hybrids from the plots treated with soil improvers had a statistically verifiable lower proline content due to the multi-year use, compared to those from the control plots. *Tyson* hybrid, which proved to be more sensitive to salt based on several test criteria, was characterized by the highest proline accumulation (*Neosol*: 5.6 µmol g^{-1}; *Explorer 21*: 6.6 µmol g^{-1}; *Rhyolite tuff:* 5.4 µmol g^{-1}; control: 9 .2 µmol g^{-1}). A significant accumulation of proline was also measured in the case of the *Sweetstar* hybrid (*Neosol:* 1.9 µmol g^{-1}; *Explorer 21*: 3.1 µmol g^{-1}; *Rhyolite tuff*: 2.6 µmol g^{-1}; control: 7.1 µmol g^{-1}). *GSS3071* (*Neosol*:

0.5 μmol g^{-1}; *Explorer 21*: 0.7 μmol g^{-1}; *Rhyolite tuff*: 1.0 μmol g^{-1}; control: 1.8 μmol g^{-1}) and *GSS8529* (*Neosol*: 0.8 μmol g^{-1}; *Explorer 21*: 1.1 μmol g^{-1}; 0.9 μmol g^{-1}; control: 1.9 μmol g^{-1}) hybrids. However, these differences proved to be statistically verifiable only in favour of the *GSS3071* hybrid treated with *Neosol* and *Explorer 21*.

4. NEW SCIENTIFIC RESULTS

1. We have found that as a result of the drastic cold stress training applied during the seedling growing period, the tested hybrids can be characterized by statistically verifiable more favourable SPAD (51.7-58.7) and NDVI (0.75-0.78) values in a season characterized by particularly large daily temperature fluctuations (like 2022).

2. We found that among in the cold stress experiment, the trained seedling growing method had a positive effect on the most important parameters from the point of view of the success of sweet corn cultivation, i.e. ear weight with and without husk. Looking at the average of the years *Sweetstar* hybrid had the highest ear weight with cover leaves compared to the results of the same genotypes from normal seedling growing method.

3. The *Sweetstar* hybrid proved to be the most cold-tolerant among the tested genotypes, which was superior in stress tolerance based on the results of ear weight with and without husk and proline accumulation, as well as SPAD and NDVI values in the 2021-2022 period.

4. Based on the test results of the salt stress experiment, we found that the soil improvement preparations used in the experiment resulted in a statistically verifiable increase in the weight of the ear with and without leaves. In the average of years and genotypes, the *Rhyolite tuff* treatment proved to be the most favourable with 27% in the case of the ear weight with husk, and 34.9% in the case of the ear weight without husk.

5. Based on the examination of the proline accumulation, I found that *Tyson* can be considered the most salt-sensitive hybrid. Considering the average of the years and soil improvement treatments, *Tyson* accumulated the largest amount of proline (6.5 μmol g^{-1}). This value is 56.9% higher than the *GSS3071* hybrid (3.7 μmol g^{-1}).

6. Based on the investigation of the effect of soil improvements on the change in the salt content of the 0-60 cm soil layer, I found that in a salt-laden environment, *Rhyolite tuff* is most suitable for creating and maintaining a soil structure that helps the leaching of harmful salts. The positive effect of the *Rhyolite tuff* treatment on the soil was also

manifested in the crop results. Considering the average of years and hybrids, the yield average was 27.2% higher than the control thanks to the *Rhyolite tuff* treatment.

5. PRACTICAL USE OF THE RESULTS

1. Based on the results of the cold stress experiment, it can be concluded that the continuous cold stress applied from the initial period of seedling cultivation ensures a degree of fitness for the sweet corn grown in the early period, which not only has a positive effect on the plant condition, but is also reflected in the yield quantity and quality parameters. Therefore, in the production of early sweet corn propagated by seedling growing, it is worthwhile to apply more drastic training during the production of the seedlings.
2. There were significant differences between the genotypes used in the cold stress experiment in terms of yield quantity and quality parameters. Syngenta's *Sweetstar* hybrid stood out statistically from the other genotypes for most of the tested parameters, so the use of this hybrid can be safely recommended for farmers involved in the cultivation of early sweet corn.
3. Based on the plant test results of the salt stress experiment, it can be established that among the soil improvements used in the experiment, the *Rhyolite tuff* treatment resulted in a statistically verifiable increase in most yield quality and yield quantity parameters of sweet corn grown in a salt-stressed environment. So, with the use of *Rhyolite tuff*, even with the increasing secondary salinization effect, it is possible to successfully grow sweet corn.
4. Syngenta's *GSS3071* hybrid clearly proved to be the most salt-tolerant in terms of most of the tested parameters. Therefore, the *GSS3071* hybrid is especially recommended for the sustainable utilization of soils characterized by less favourable properties in terms of salt content. In addition to the Syngenta's *GSS3071* hybrid *GSS8529* hybrid also proved to be promising in terms of several parameters, so this hybrid can also be promising for the utilization of less favourable areas. On the other hand, growing the *Tyson* hybrid in a salt-laden environment is not recommended at all.
5. By using soil improvers and soil conditioners, not only can harmful salts be washed out into deeper layers, but by improving the structure of the soil, its water capacity and moisture supply capacity can also be increased. By mitigating the salt effect (salinity), a sustainable cultivation technology can be ensured even in areas with less favourable agro-ecological characteristics, exposed to the risk of primary or secondary salinization, but irrigated, so they can be included in sweet corn cultivation.

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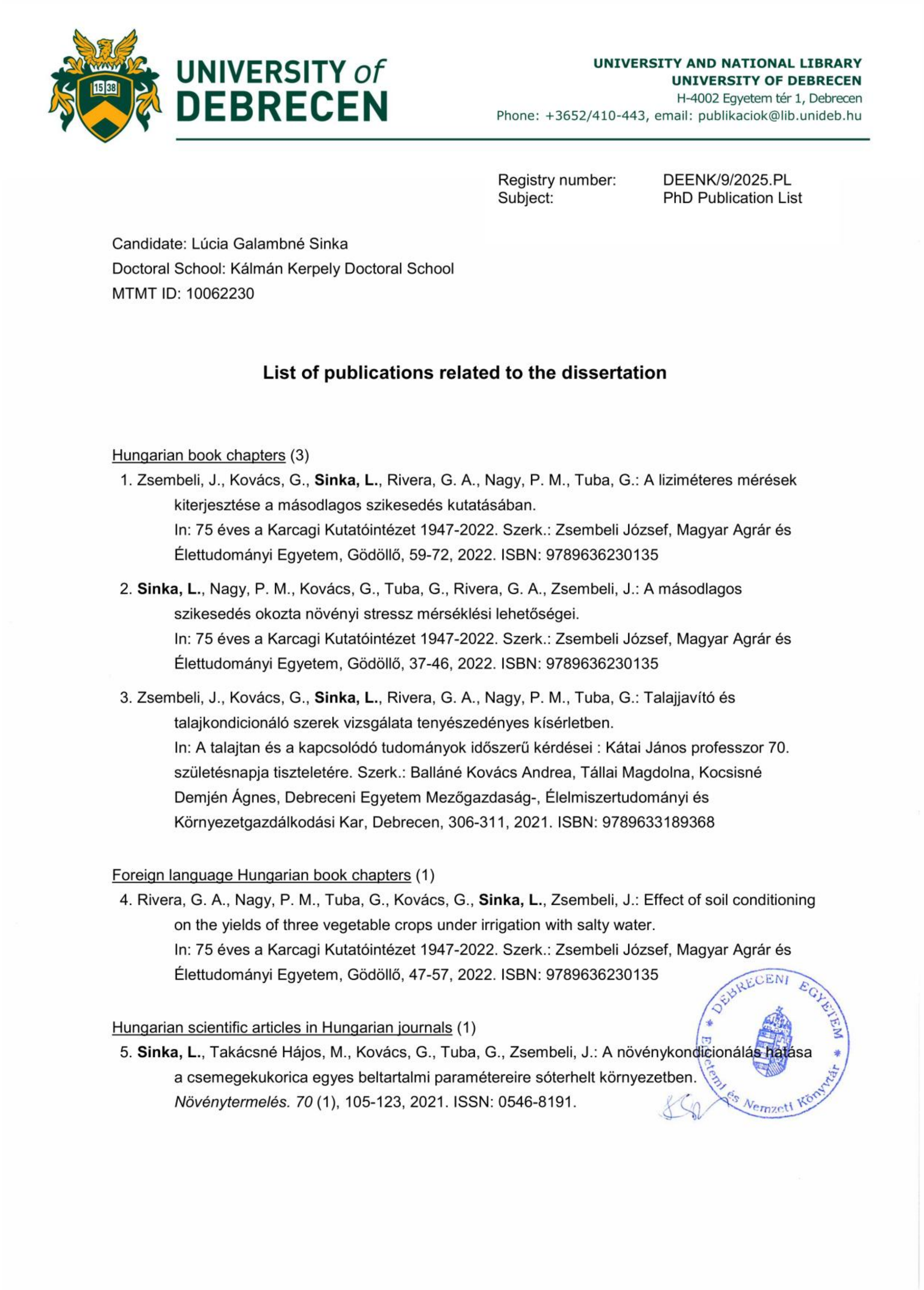
7. LIST OF PUBLICATIONS RELATED TOT HE DISSERTATION



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Subject: PhD Publication List

Candidate: Lúcia Galambné Sinka
Doctoral School: Kálmán Kerpely Doctoral School
MTMT ID: 10062230

List of publications related to the dissertation

Hungarian book chapters (3)

1. Zsembeli, J., Kovács, G., **Sinka, L.**, Rivera, G. A., Nagy, P. M., Tuba, G.: A liziméteres mérések kiterjesztése a másodlagos szikesedés kutatásában.
   In: 75 éves a Karcagi Kutatóintézet 1947-2022. Szerk.: Zsembeli József, Magyar Agrár és Élettudományi Egyetem, Gödöllő, 59-72, 2022. ISBN: 9789636230135
2. **Sinka, L.**, Nagy, P. M., Kovács, G., Tuba, G., Rivera, G. A., Zsembeli, J.: A másodlagos szikesedés okozta növényi stressz mérséklési lehetőségei.
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3. Zsembeli, J., Kovács, G., **Sinka, L.**, Rivera, G. A., Nagy, P. M., Tuba, G.: Talajjavító és talajkondicionáló szerek vizsgálata tenyészedényes kísérletben.
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Foreign language scientific articles in international journals (3)

8. **Sinka, L.**, Takácsné Hájos, M., Kovács, G., Tuba, G., Rivera, G. A., Zsembeli, J.: Assessment of 1-Triacontanol treatment of sweet corn (Zea mays L. convar. saccharata) aimed at the improvement of salt tolerance based on a pot experiment.
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Foreign language conference proceedings (1)

11. **Sinka, L.**, Rivera, G. A., Tuba, G., Zsembeli, J.: Mitigation of salt stress caused by secondary salinization.
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12. **Sinka, L.**, Takácsné Hájos, M., Czellér, K., Tuba, G., Zsembeli, J.: A növénykondicionálás hatása a csemegekukorica beltartalmi paramétereire sóterhelt környezetben = Effect of plant conditioning on kernel quality of sweet corn in saline environment.
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13. **Sinka, L.**, Takácsné Hájos, M., Kovács, G., Tuba, G., Rivera, G. A., Zsembeli, J.: Assessment of 1-triacontanol treatment of sweetcorn (zea mays l. convar. saccharata) aiming its salt tolerance improvement on the base of a pot experiment.
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List of other publications

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14. Kovács, G., Tuba, G., **Sinka, L.**, Nagy, P. M., Rivera, G. A., Zsembeli, J.: A klímaváltozás lokális hatásainak értékelése a szélsőséges időjárási helyzetek tükrében.
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16. Zsembeli, J., **Sinka, L.**, Czellér, K., Tuba, G., Kovács, G., Juhász, C.: A harmat mennyiségének meghatározása súlyliziméterekkel.
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Foreign language international book chapters (2)

17. Zsembeli, J., Czellér, K., **Sinka, L.**, Kovács, G., Tuba, G.: Application of lysimeters in agricultural water management.
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20. Tuba, G., Gulybán, O., Kovács, G., Nagy, P. M., **Sinka, L.**, Zsembeli, J.: Az évenként végzett talajlazításra alapozott művelési rendszer értékelése a talaj penetrációs ellenállása alapján.
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23. Zsigrai, G., Kneip, A., Zsembeli, J., Kovács, G., Tuba, G., **Sinka, L.**: A Furmint szárazanyag produkciójára és vízfelhasználására gyakorolt alanyhatások vizsgálata súlyliziméterekben.
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Foreign language scientific articles in Hungarian journals (4)

25. Zsembeli, J., Tuba, G., Kovács, G., **Sinka, L.**, Nyaboke, C.: Soil related environmental considerations of farmers in the Great Hungarian Plain.
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Foreign language scientific articles in international journals (5)

29. Juhász, C., Huzsvai, L., Kovács, E., Kovács, G., Tuba, G., **Sinka, L.**, Zsembeli, J.: Carbon-dioxide efflux of bare soil as a function of soil temperature and moisture content under weather conditions of warm temperate dry climate zone.
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Acta Univ. Sapientiae, Agric. Environ. 11 (1), 72-82, 2019. ISSN: 2065-748X.
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35. Czellér, K., Tuba, G., Kovács, G., **Sinka, L.**, Zsembeli, J., Percze, A.: A Miscanthus giganteus vízfelhasználási hatékonyságának vizsgálata liziméteres kísérletben.
    In: XXI. századi vízgazdálkodás a tudományok metszéspontjában : II. Víztudományi Nemzetközi Konferencia. Szerk.: Jakab Gusztáv, Csengeri Erzsébet, Szent István Egyetem Agrár- és Gazdaságtudományi Kar, Szarvas, 48-55, 2019. ISBN: 9789632698083

36. **Sinka, L.**, Czellér, K., Tuba, G., Kovács, G., Zsembeli, J.: A légköri harmat éves mennyisége és szerepe a vízforgalomban.
    In: Alkalmazkodó vízgazdálkodás: lehetőségek és kockázatok. Szerk.: Jakab Gusztáv, Tóth Attiláné, Csengeri Erzsébet, Szent István Egyetem Agrár- és Gazdaságtudományi Kar Tessedik Campus, Szarvas, 171-177, 2018. ISBN: 9789632697369

37. Zsembeli, J., Czellér, K., **Sinka, L.**, Tuba, G.: A talaj nedvesség- és sóprofiljának szabályozása öntözéssel.
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Foreign language conference proceedings (5)

38. Zsembeli, J., **Sinka, L.**, Tuba, G., Rivera, G. A., Kovács, G.: Water use of lawns determined in weighing lysimeters.
    In: Lysimeter und Bodenwasserhaushalt: Trockenheit - Bewässerung - Ertragssicherheit / Brigitte Marold, Höhere Bundeslehr- und Forschungsanstalt für Landwirtschaft, Raumberg-Gumpenstein, 133-138, 2021. ISBN: 9783902849830

39. **Sinka, L.**, Rivera, G. A., Czellér, K., Tuba, G., Zsembeli, J.: Simulation of the irrigation practice applied in the hobby gardens of Karcag in simple drainage lysimeters.
    In: Lysimeter - a perfect tool for quantifying fluxes of water, nutrients and pollutants. Hrsg.: Brigitte Marold, Höhere Bundeslehr- und Forschungsanstalt für Landwirtschaft, Raumberg-Gumpenstein, 171-174, 2019. ISBN: 9783902849649

40. Czellér, K., Tuba, G., Kovács, G., **Sinka, L.**, Zsembeli, J., Percze, A.: Water use efficiency of Miscanthus giganteus under different irrigation doses.
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41. Czellér, K., Zsembeli, J., **Sinka, L.**, Kovács, G., Streda, T., Stredova, H., Cepuder, P., Nolz, R.: Determination of the amount of dew using weighing lysimeter data.
    In: Lysimeterforschung - Möglichkeiten und Grenzen Lysimeter research - options and limits / Brigitte Marold, Höhere Bundeslehr- und Forschungsanstalt für Landwirtschaft, Raumberg-Gumpenstein, 181-184, 2017. ISBN: 9783902849458
42. Zsembeli, J., Czellér, K., Tuba, G., Szűcs, L., **Sinka, L.**: Effect of Irrigation with Saline Water on the Soil and Legumes in Simple Drainage Lysimeters.
    In: Lysimeterforschung - Möglichkeiten und Grenzen Lysimeter research - options and limits / Brigitte Marold, Höhere Bundeslehr- und Forschungsanstalt für Landwirtschaft, Raumberg-Gumpenstein, 189-192, 2017. ISBN: 9783902849458

<u>Hungarian abstracts</u> (3)

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    In: 17. Magyar Magnézium Szimpózium. Szerk.: Takácsné Hájos Mária, Vojnich Viktor, Magyar Kémikusok Egyesülete, Budapest, 25-26, 2021. ISBN: 9786156018069
44. **Sinka, L.**: Karcagi zártkertekben jellemző öntözési szokások szimulálása liziméterekben zöldbab jelzőnövénnyel.
    In: XXXIV. Országos Tudományos Diákköri Konferencia. Agrártudományi Szekció. Előadáskivonatok.. Szerk.: Juhász Csaba, Juhász Lajos, Gyüre Péter, Vári Erzsébet, Debreceni Egyetem Mezőgazdaság-, Élelmiszertudományi és Környezetgazdálkodási Kar, Debrecen, 155-155, 2019. ISBN: 9789634900788
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<u>Foreign language abstracts</u> (3)

46. Zsembeli, J., Tuba, G., Kovács, G., **Sinka, L.**, Nagy, P. M., Rivera, G. A., Nyaboke, C.: Soil related environmental considerations of farmers in the Great Hungarian Plain.
    In: Trends and challenges in soil-crop management : Bokk of abstracts. Eds.: Vladimir Smutny, Vojtech Lukas, Mendel University, Brno, 18, 2022. ISBN: 9788075098474
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    In: Vth Horticulture and Landscape Planning Conference from Transylvania. Ed.: Benedek Klára, Sapientia Erdélyi Magyar Tudományegyetem, Marosvásárhely, 17-17, 2019.

48. Zsembeli, J., **Sinka, L.**, Tamás, J., Juhász, C.: Mitigation possibilities of secondary salinization induced by irrigation with saline water.
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Informational/educational articles (1)

49. **Sinka, L.**: A palántanevelés és a hibridválasztás jelentősége a korai csemegekukorica-termesztésben.
Agroforum. 31, 44-47, 2020. ISSN: 1788-5884.

Total IF of journals (all publications): 7,1
Total IF of journals (publications related to the dissertation): 0

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

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