Theses of Doctoral (PhD) dissertation

DEVELOPMENT OF THE ENVIRONMENTAL FRIENDLY TECHNOLOGY OF HYBRID MAIZE SOWING SEED PRODUCTION

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1. PRELIMINARIES AND OBJECTIVES OF THE DOCTORAL THESIS

Field crop production is mainly based on the utilisation of natural resources (e.g. climate, soil, sowing seed, etc), but the exploitation of our resources has become more and more expressed, even harmful sometimes (*Szász*, 2002).

During the development of cultivation and crop production, mankind significantly affected the surface of the Earth by agricultural activities and soil characteristics. The industrial-like, strongly chemicalised farming method which neglects production site conditions started such harmful processes in the soil that led to the reduction of soil fertility (*Ruzsányi and Pepó*, 1999). Negative effects like this are the deterioration of fertile soil (erosion, deflation), reduction of the organic matter content and the biological activity of the soil, acidification, development of wet and bog soils, salinification, deterioration of the soil structure, compaction and contamination of soil (*Ángyán and Menyhért*, 1988).

Soil use does not necessarily lead to the deterioration of the conditions of our soil stock. Despite the strengthening unfavourable effects, the quality and fertility of our soils can be protected and maintained (*Várallyay*, 2001). The maintenance of the natural conditions and fertility of our soils makes it necessary to develop and introduce an adapting or sustainable agriculture (*Ángyán et al.*, 1997) that calls for ecologic aspects, production site endowments besides economic factors and makes it possible to carry out economical production with the lowest possible environmental load (*Szász*, 1997; *Sárvári*, 1998; *Loch*, 1999; *Pepó*, 2007). We have to enforce the principles of sustainable development also in nutritional management, therefore, we have to synchronise production and environmental needs and we also have to apply the principles of environmental friendly nutritional replenishment which adapts to production site conditions (*Láng and Csete*, 1992).

In order to reach high average yields and good quality, organic and inorganic nutritive material has to be used, whereas irrational nutritional replenishment could harm our environment (*Szabó*, 1999). Rational fertilisation does not pollute the environment, as we only apply the fertiliser that is needed for the undisturbed development of crops, thereby reducing fertiliser loss to its minimum (*Kádár*, 1992; *Németh*, 1995). Also, it is important from the aspect of environmental protection to adapt nutritional replenishment to crops' needs, to the nutritive uptake dynamism and the conditions of the production site (*Németh*, 2001). We have to switch mechanical fertilisation practice to the dynamic one, which consists of the following basic elements: the optimal utilisation of available sources of nutrients, consideration of the nutritional cycle, more expressed consideration of the long-term effect of fertilisation, avoiding the unwanted side-effects of fertilisation (*Németh and Várallyay*, 1998).

By evaluating the soil characteristics of the maize sowing seed production in Hajdúszoboszló, the differences between soil types and the changes that occurred in the soil over long period (40 years), as well by examining the aspects resulting in the heterogeneity of sowing seed maize populations and the yield increasing effectivity of natural foliar fertilisers, my objective was to contribute to rational and sustainable nutritional management.

2. Research methods

2.1. Method of evaluating soil endowments

The size of the examined plough land was 580.4 ha, located in the southwestern and northeastern part of Hajdúszoboszló. The characterisation of maize sowing seed production was done by GIS tools based on genetic soil maps. The scanned genetic soil map of the south-southwestern and northeastern area of Hajdúszoboszló put into the system of coordinates of the Unified National Projection system (EOV) was provided by the Crop and Soil Protection Board of the Hajdú-Bihar county Agricultural Management Office. I digitalised the map and developed the GIS database using *ArcGis 9.1*.

I used *Trimble GPS Pathfinder ProXH* and *ArcPad 7.0* to mark off the area of maize sowing seed production within the production area. I adjusted the polygons of the plots to the digitalised genetic soil map of the production area, therefore, the spatial location of the typical soil types, subtypes, variants and profile exploration points became visible. Considering these information, the logging of sampling points in the case of every soil type and profile exploration point was of primary importance during the designation of sampling points. 119 soil sampling points were selected altogether, 36 of which were located in the areas of the profile explorations carried out in 1964-

66. I gave each sampling point a unique code which provided an opportunity to identify soil samples on the basis of sampling points.

During the soil sampling, I used *Trimble GPS Pathfinder ProXH* and *ArcPad 7.0* on the basis of a genetic soil map by an *Eikelkamp* manual auger on the previously designated locations every 4 hectares on average in the 0-30 cm depth of the soil between 20th May 2006 and 12th June 2006. I repeated the soil sampling during the autumn between 19th September 2006 and 2nd October 2006, thereby collecting 238 soil samples from 119 sampling points altogether. The soil analyses were carried out on the Department of Agrochemistry and Soil Science of the University of Debrecen, Centre of Agricultural Sciences.

2.2. Method of examining changes that occurred in the soil during a long period

During the designation of the soil sampling points of the maize sowing seed production area, I pointed out 36 sampling points along the locations of the profile explorations done in 1964-66. I compared the results of the 2006 soil sampling to those logged in the soil analysis report done during the profile explorations in 1964-66, that was provided by the Crop and Soil Protection Board of the Hajdú-Bihar county Agricultural Management Office. Both the profile explorations and the 2006 soil sampling were done by a unique identification method, therefore, I had the opportunity to compare the results in pairs, using *SPSS for Windows 14.0*. I used Kolmogorov-Smirnov test to examine the normality of variables, then, I used a paired t test or Wilcoxon test to determine the significant differences between the soil analysis results of 1966 and 2006, depending the examination of normality. I performed the statistical evaluation at the 5% level of significance in all cases.

2.3. Comparative analysis of soil types

During the evaluation of the differences between soil types, I compared the average results of soil analysis and areas and territorial proportion of the soil patches that have different acidity, plasticity, salt content, lime, humus, nitrogen, phosphorus, potassium and zinc supply.

During the statistical evaluation, I used a Kolmogorov-Smirnov test to examine the normality of variables to be compared. The statistical evaluation of the difference between soils in the case of soil characteristics that do not have a normal distribution was done by a non-parametric test (Kruskal-Wallis H test), whereas a parametric test (Duncan test and t test) was used in the case of soil characteristics that have normal distribution. As regards the evaluation of the differences between soil types, I used Duncan's test concerning soil parameters that have the same variance and t test in the case of variables with different variance. I performed the statistical evaluation on the basis of the analytical results of 228 soil samples, as a 5% level of significance.

2.4. The examination method of the reliability of SPAD measurements

During the examination of the heterogeneity of the maize sowing seed population and efficacy analysis of natural foliar fertilisers, I also performed SPAD measurements using the Minolta SPAD-502 (Soil Plant Analysis Development) meter, therefore, I examined the reliability and accuracy of the measurements, too.

I examined the distribution of chlorophyll within the leaf-blade on 29 54-56 cm long leaves grown from the 6-7 nodes in an inbred population after tasselling. I designated 48 measurement points on the leaf every 2 cm (*Figure 1*) then I logged the SPAD results per measurement point in a database.

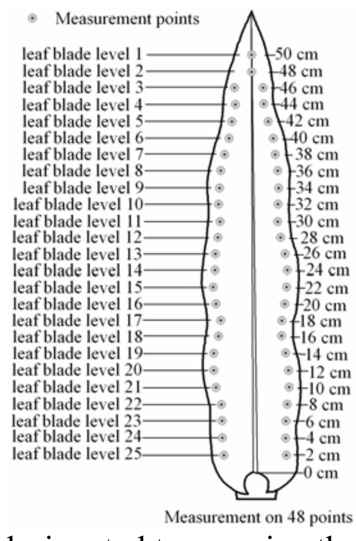

Figure 1. Measurement points designated to examine the distribution of SPAD values

I used *SPSS for Windows 14.0* to evaluate the results. I averaged the results obtained from the examined leaves per measurement point and I evaluated their distribution alongside the leaf.

Based on the 48 point measurement results, I showed the SPAD results in a variance-mean graph and then I evaluated the correlation between average SPAD values and variances using a regression analysis.

Considering the distribution of chlorophyll alongside the leaf-blade, I determined measurement methods consisting of 5, 10, 14, 20 and 30 measurement points. As for the 5 point measurement, I designated two points in the lower part and three points in the upper part of the leaf. In the case of the 10, 14, 20 and 30 point measurements, I set out the first two points on the right and left side of the leaf-blade's basal part and I distributed the rest along the right and left side of the leaf-blade proportionally (*Figure 2*).

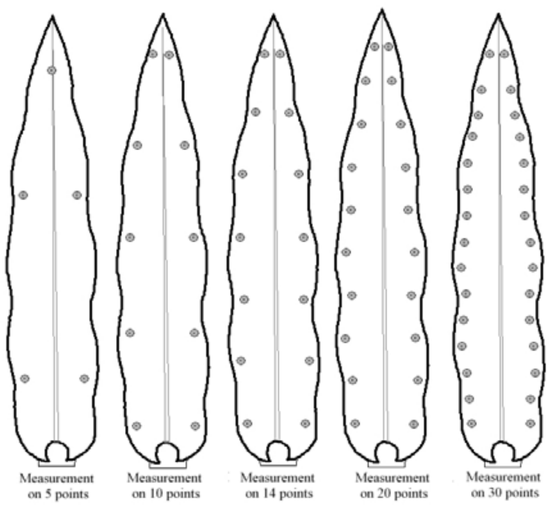

Figure 2. Location of measurement points on the leaf-blade in the 5, 10, 14, 20 and 30 point measurement methods

Using the results of the 48 point measurements, I collated SPAD values in 30 replications per leaf in accordance with the 5, 10, 14, 20 and 30 point measurement methods. As for the 5 point method, I collated randomised data for the measurement point at the leaf apex from the values measured at the 1st and 2nd leaf-blade levels, whereas I used data from the 9th, 10th and 11th leaf-blade levels in the case of the two measurement points marked out in the upper third of the leaf and the measurement points in the lower third were connected with values measured at the 21st, 22nd and 23rd leaf-blade levels. As for 10, 14, 20 and 30 point measurement methods, the collating of SPAD values was also done at leaf-blade levels. Based on the data collated by different measurement methods, I determined the average SPAD values of leaves and I also calculated the standard deviation within the leaf and between leaves by breaking up the variance components. I used regression analysis to evaluate the correlation of the number of measurement points and the average SPAD readings, the standard deviation within the leaf and between leaves. The determination of the method suitable for the detection of differences between leaves was done by variance analysis (ANOVA). Based on the data collated in 30 replications, I examined the differences between leaves in each replication and determined the value of F test statistics. Based on the average of F values, I evaluated the confidence level of the given measurement method in detecting the differences between leaves.

2.5. Method of evaluating the heterogeneity occurring in a sowing seed maize population

In 2007, I examined the heterogeneity of a sowing seed maize population in the southern production area of Hajdúszoboszló on calcareous meadow chernozem soil. I chose the plot which is the least uniform from the aspect of the habitus of the crop population, but it homogeneous in its soil type.

I performed the heterogeneity examination of the crop population in an inbred female line in a zero male sowing on a 10.4 ha sample plot with basic fertiliser treatment (160 $kg{\cdot}ha^{-1}$ N, 80 $kg{\cdot}ha^{-1}$ P_2O_5, 70 $kg{\cdot}ha^{-1}$ K_2O). In the population, I made random measurements of 100 plants and I designated 8 height categories on the basis of the measurement results: 20-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm, 100-110 cm. I performed the local measurements every two lines. I measured the height of the crop population using a measurement rod, thereby determining which height category the crop population falls into in the given measurement point, whereas I logged the coordinates of the measurement point using *Trimble GPS Pathfinder ProXH* and *ArcPad 7.0*. I made measurements of the plant height on 12633 points until the intersection of the remaining two upper leaves between 16/07/2007 and 20/07/2007. The average area of the measurement points was 8.2 m^2.

The aerial bordering of the population patches that can be characterised by different plant height data and the designation of the sampling points were done using *ArcGis*

9.1. Due to their low territorial proportion, I merged the 20-40 cm high population patches with the 40-50 cm high parts of the population. Based on the measurement results, I designated 4-8 sampling points in every plant height category (35 altogether) (*Figure 3*).

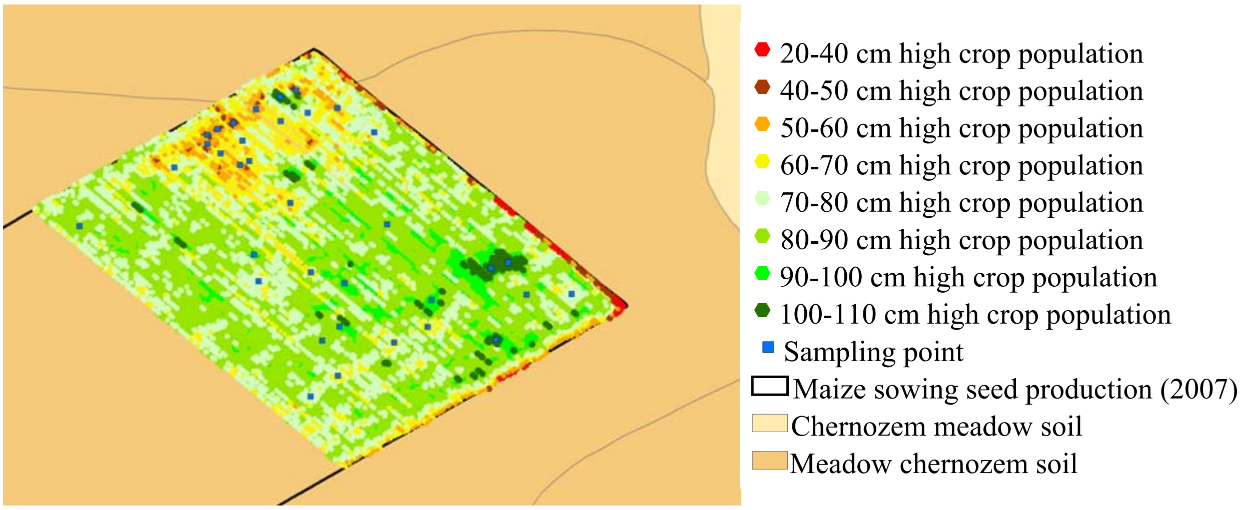

Figure 3. Change of crop height on the sample area

I measured the SPAD values of leaves in every measurement point, I collected yield, leaf and soil samples.

I performed SPAD measurements on 27/07/2007 (after tasselling), using a Minolta SPAD-502 meter on 10 plants per measurement point, taking the most developed leaf and taking 10 points per leaf. I carried out the measurements on proportionally distributed points alongside the leaf-blade, taking 5-5 points on the right and left side of the leaf-blade.

The yield and leaf sampling (leaves under the ear) took place on 29/08/2007 and 30/08/2007, taking 10 plants per sampling point, whereas soil samples were taken on 25/09/2007 in the 0-30 and 30-60 cm depth, using an *Eikelkamp* manual auger. Altogether, I collected 350 yield samples, 350 leaf samples and 70 soil samples.

The leaf analysis and the soil analyses were carried out on the on the Department of Agrochemistry and Soil Science of the University of Debrecen, Centre of Agricultural Sciences.

I used regression analysis to examine the correlations between the grain number per plant (grains·stem^{-1}) and SPAD values, and between yield (g·stem^{-1}) and SPAD values.

Based on the regression equations, taking SPAD values as a basis, I estimated the average grain number and yield per plant height category, then I determined the accuracy of estimation by comparing the estimated values to the measured ones.

I used main component analysis to search for the factors responsible for the heterogeneity in yield results. I examined the correlations between the number of maize grains (grains•stem^{-1}) and the nutrients taken up; yield (g•stem^{-1}) and the nutrients taken up; the proportions of nutrients measured in leaves and the number of grains per plant; yield and nutrient proportions; soil analysis results and grain number; and yield and soil analysis results.

The correlation between the amount of nitrogen taken up by the plant and SPAD values was evaluated by regression analysis. Based on the regression equation, taking SPAD values as a basis, I estimated the average nitrogen content of leaves per plant height category, then I determined the accuracy of estimation by comparing the estimated values to the measured ones. I searched for the soil factors responsible for nitrogen uptake and SPAD value heterogeneity by using main component analysis. The statistical evaluations were done at a 5% level of significance.

2.6. Method of examining the efficacy of natural foliar fertilisers

I examined the efficacy of natural foliar fertilisers in three subsequent years (2006, 2007, 2008) in the southern production area of Hajdúszoboszló.

The soil of the examined plots was loamy adobe on the basis of Arany's plasticity value (45-46), it was slightly alkaline ($pH_{(H_2O)}$ = 8.1-8.3), slightly calcareous ($CaCO_3$ = 1.6-3.0 m/m%), it had a low salt content (Total water-soluble salt = 0.013 m/m%), it contained adequate humus (2.92-3.12 m/m%), average nitrogen (Total nitrogen = 1701-1814 mg•kg^{-1}), and it contained a low amount of zinc (KCl-EDTA Zn = 1.07-1.62 mg•kg^{-1}). The experimental area was moderately supplied with phosphorus and potassium (AL-P_2O_5 = 161-169 mg•kg^{-1}, K_2O = 286-287 mg•kg^{-1}) in 2006 and 2007, whereas the area of examination was weakly supplied in 2008 (AL-P_2O_5 = 84 mg•kg^{-1}, K_2O = 218 mg•kg^{-1}) (*Table 1*).

Table 1. Average values of the soil analysis results in the experimental areas

Examined soil parameters	Examined area		
	2006	2007	2008
Arany type plasticity index	46	45	45
$pH_{(H_2O)}$	8.3	8.2	8.1
$CaCO_3$ (m/m%)	3.0	2.2	1.6
Total water-soluble salt content (m/m%)	0.013	0.013	0.013
Humus (m/m%)	3.01	3.12	2.92
Total nitrogen ($mg \cdot kg^{-1}$)	1750	1814	1701
AL-P_2O_5 ($mg \cdot kg^{-1}$)	161	169	84
AL-K_2O ($mg \cdot kg^{-1}$)	287	286	218
KCl-EDTA Zn ($mg \cdot kg^{-1}$)	1.45	1.62	1.07

During all three years, I performed the analyses in sowing seed maize population in zero male sowing with basic fertiliser treatment. The previous crop was sowing seed maize in all cases. Sowing (end of April – beginning of May) was always done using a zero male method with Monosem sowing machine in the case of female lines and Optima in the case of male lines. 130-160 $kg \cdot ha^{-1}$ nitrogen, 80-85 $kg \cdot ha^{-1}$ phosphorus and 70-80 $kg \cdot ha^{-1}$ potassium were applied as basic fertiliser. 10-15 percent of phosphorus, potassium and nitrogen was applied in the form of complex fertiliser during the autumn, whereas 85-90% of nitrogen was applied during the spring, directly before seed-bed preparation. I planned the treated and non-treated areas to be 12 m wide (16 female lines) and I designated the sampling points in four replications using *ArcGis 9.1*. I used Natur Plasma, Natur Plasma enriched with zinc, Natur Vita and Amalgerol Premium during the examinations.

Examined products:

- Natur Plasma (*Chlorella algae concentrate enriched with nutrients*)
- Natur Vita (*pulverised version of Chlorella algae concentrate*)
- Amalgerol Premium (*vegetable volatile oils, mineral oils, alginate, mannitol, laminarin, algae extract, macro and microelements*)

In 2006, I used Natur Plasma in population treatment in 2.5% concentration (6.4 $l \cdot ha^{-1}$ with 250 $l.ha^{-1}$ water). In 2007, I performed population treatment with Natur Plasma and Natur Plasma enriched with zinc in 2.5% concentration (6.4 $l \cdot ha^{-1}$, with

250l water), with Amalgerol Premium in 1.0% concentration (2.5 l•ha^{-1}, with 250 l•ha^{-1} water) and 250 g•ha^{-1} Natur Vita (with 250 l•ha^{-1} water). As for stubble-field treatment, I applied Amalgerol Premium in 2.0% concentration (6.0 l•ha^{-1}, with 300 l•ha^{-1} water) and Natur Plasma in 3.2% concentration (10 l•ha^{-1}, with 300 l•ha^{-1} water). In 2008, I used the 2.5% dose of Natur Plasma (6.4 l•ha^{-1}, with 250 l•ha^{-1} water), 1.0% dose of Amalgerol Premium (2.5 l•ha^{-1}, 250 l•ha^{-1}) and 250 g•ha^{-1} dose of Natur Vita in population treatment. The population treatments took place twice, at the 5-8 leaf stage and one-one and a half weeks before tasselling, using a Berthoud Boxer 3000 sprayer.

Stubble-field treatments were done on 15/10/2006 with a Berthoud Boxer 3000 sprayer on the maize stubble-field. The treatment was preceded by stalk crushing and harrowing, after which the products were directly applied to the soil surface, followed by a hollow (5-10 cm) disk cultivation. I evaluated the effect of the stubble-field treatment in sowing seed maize population in 2007. In 2008, I also examined the efficacy of the combinations of foliar fertilisers in population treatments. Amalgerol Premium (5.0 l•ha^{-1}) was applied in combined treatment on 09/06/2008 and Natur Plasma (5.0 l•ha^{-1}) was applied on 07/07/2008 and on 21/07/2008. In order to be able to evaluate the efficacy, I collected samples from 10 stems per sampling point, altogether 40 yield samples per treatment. I determined the number of maize grains per ear and the weight of air-dry samples, too. In 2008, I also performed SPAD measurements in the treatments, using a Minolta SPAD-502 meter. I carried out the measurements on 10 plants per sampling point on the 6th-7th leaf, from proportionally distributed locations alongside the entire length of the leaf-blade, taking 5-5 points on the right and left side of the leaf-blade. I performed the measurements three times, before the first treatment (05/06/2008), between the two treatments (11/07/2008) and after the second treatment (06/08/2008). During the evaluation of the number of maize grains (grains•stem^{-1}), yield results and SPAD readings, I used a Kolmogorov-Smirnov test to examine the normality of the distribution of data and the and the identity of the variances of the grain number, yield and SPAD readings of the treatments. The normality examination showed normal distribution in all cases, therefore, I chose a parametric test to compare the mean values. I used Duncan's test to simultaneously compare mean values, then I verified the obtained significance results of the treatments that do not have identical variances using a t test.

3. Main Statements of the Thesis

3.1. Soil endowments of the maize sowing seed production area

The main part (67.3%) of the maize sowing seed production area is alkaline soils, but there was also a significant proportion of slightly acidic areas (18.1%). The entire examined area had low salt content and 98.5% had very low or low lime content. The majority of soils around Hajdúszoboszló was well and adequately supplied with humus (70.1%), moderately supplied with nitrogen (100%) and weakly supplied with zinc (96.5%). The levels of phosphorus and potassium supply varied, there were weakly, moderately, adequately, well and very well supplied areas. The highest proportion of soils had adequate and moderate levels of supply (AL-P_2O_5: 50.4%; AL-K_2O: 55.4%).

From the aspect of maize sowing seed production, the high proportions of soils belonging to production category 1 (98.1%) and chernozem soils (87.5%) were very favourable. Nevertheless, it is unfavourable that the ratio of slightly acidic (18.1%) soils and soils that have low lime content (98.5%), as well as those that are weakly supplied with nutrients are also high.

3.2. Changes that occurred in the soil over a long period

I compare the results of the soil sampling in 2006 to those logged in the soil analysis report of the profile explorations in 1964-66.

As regards $pH_{(H_2O)}$ and lime content, the Wilcoxon test showed identity between the two research periods, whereas the humus content, total water-soluble salt content, total nitrogen content, AL-soluble phosphorus and potassium contents were shown to have significant differences on the basis of the paired t test. Over 40 years, there were significant decreases in humus content (0.99 m/m%), the total water-soluble salt content (0.034 m/m%) and the total nitrogen content (551 $mg \cdot kg^{-1}$), and there were significant increases in the amount of AL-P_2O_5-(112 $mg \cdot kg^{-1}$) and the AL-K_2O content (92 $mg \cdot kg^{-1}$).

The results showed the humus-consuming feature and negative effect (decrease of humus content) of the activity carried out in the area, as well as the success of replenishing phosphorus and potassium fertilisation performed in the ’70s.

3.3. Comparative evaluation of the main soil types characterising the areas of maize sowing seed production

The entire area of chernozem meadow soil belonged to the loamy adobe physical category, whereas there were adobe soils among the two other types at a 3.0% frequency on meadow chernozem soil and 36.4% on calcareous chenozem soil.

The $pH_{(H_2O)}$ of the soil samples taken from chernozem meadow soil fell into the slightly alkaline range, whereas I also identified slightly acidic (2.8% and 54.6%) and neutral areas (4.7% and 33.3%) in the case of meadow chernozem and calcareous chernozem soils.

The total water-soluble salt content of the examined soils was not more than the lower bound of the salt content characteristic of low salt content soils (0.1%) and the lime content of the examined soils was also low. The highest territorial proportions were represented by calcareous chernozem soils with very low lime content (96.9%) and chernozem meadow and meadow chernozem soils with low lime content (90.6% and 74.5%).

The proportion of soils adequately supplied with humus was the highest on chernozem meadow soil (85.8%), whereas it was lower on meadow chernozem soil (55.1%) and the lowest on calcareous chernozem (24.2%). The majority of calcareous chernozem soils (69.7%) fell into the category of soils moderately supplied with humus and the nitrogen content of all three soil types was average in the whole area (*Figure 4*). As regards the phosphorus content, the highest territorial proportion was represented by the average and adequate level of supply category on all three soils. The territorial frequency of the two supply level categories was 66.7% on calcareous chernozem soil, 60.4% on chernozem meadow soil and 41.4% on meadow chernozem soil. The proportion of areas very weakly or weakly supplied with phosphorus was higher in the case of meadow chernozem soil (29.3%) than those of chernozem meadow soil (19.1%) and calcareous chernozem soil (18.2%). The territorial proportion of soils well and very well supplied with phosphorus was the highest on meadow chernozem soil (29.3%) and it was lower on chernozem meadow (20.5%) and the lowest on calcareous chernozem soil (15.1%) (*Figure 5*).

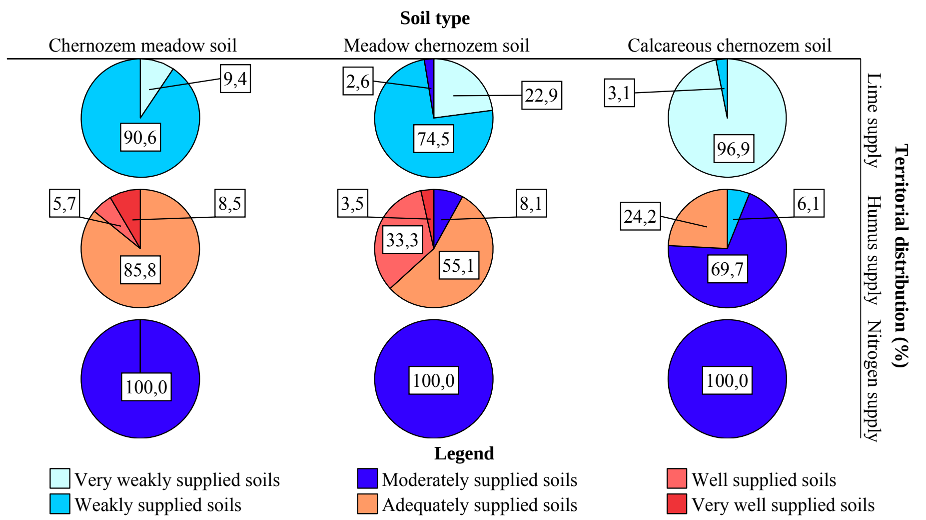

Figure 4. Territorial distribution (%) of soils with different lime, humus and nitrogen content within each soil type

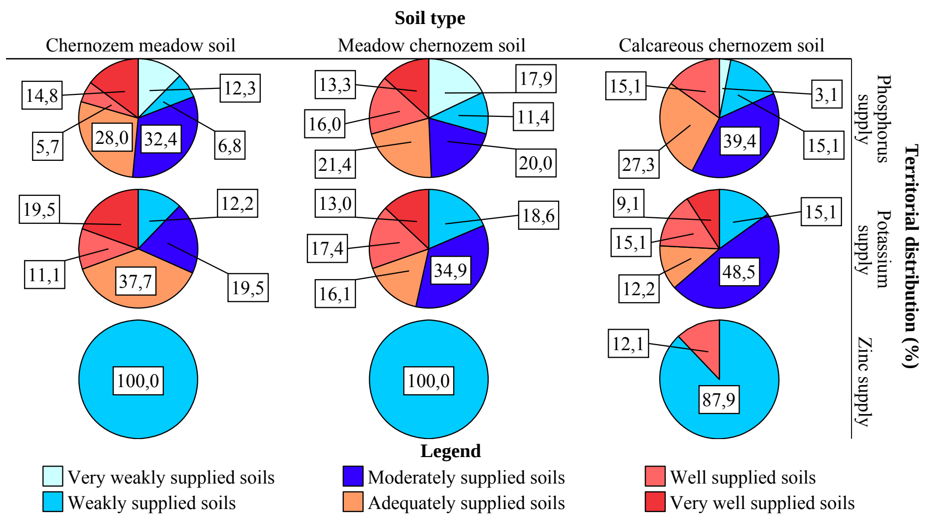

Figure 5. Territorial distribution (%) of soils with different phosphorus, potassium and zinc content within each soil type

Similarly to phosphorus, the level of potassium supply also showed great diversity concerning all three soils, but there were no soils that are very weakly supplied with potassium on any of the soil types, as opposed to phosphorus. The ratio of areas moderately and adequately supplied with potassium was more than 50% on all three soil. It exceeded 50% by 10.7% on calcareous chernozem soil, by 7.2% on chernozem meadow soil and by 1.0% on meadow chernozem soil. The territorial frequency of soils weakly supplied with potassium on meadow chernozem soil (18.6%) was more than that of calcareous chernozem soil (15.1%) and chernozem meadow soil (12.2%). As for soils well and very well supplied with potassium, I obtained nearly similar values in the case of chernozem meadow and meadow chernozem soils (30.6% and 30.4%), whereas the territorial frequency of such soils was lower in the case of calcareous chernozem soil (24.2%).

The entire area of chernozem meadow soil and meadow chernozem soil was weakly supplied with zinc, whereas 12.1% of the calcareous chernozem soil showed good zinc supply (*Figure 5*).

The Duncan's test showed no significant difference between the salt contents of the examined soils. The zinc content of the calcareous chernozem soil was shown to be significantly higher than that of meadow chernozem and chernozem meadow soils, but there was no significant difference between the zinc contents of meadow chernozem and chernozem meadow soils.

Based on the significance results of the t test, there was no significant difference between the humus-, AL-P_2O_5- and total nitrogen contents of chernozem meadow and meadow chernozem soils, whereas the AL-K_2O content was identical in all three soils.

As for $pH_{(H_2O)}$, t test showed significant differences in the case of all three soil types. The $pH_{(H_2O)}$ of chernozem meadow soil was higher than that of meadow chernozem by 0.2 and also higher than the value obtained in the case of calcareous chernozem soil by 1.3. The difference between the soil $pH_{(H_2O)}$ of meadow chernozem and the calcareous chernozem soil was 1.1. There was a significant difference between the chernozem meadow and the calcareous chernozem soil as regards their humus content (0.55 m/m%), AL-P_2O_5- (45 $mg{\cdot}kg^{-1}$) and total nitrogen content (320 $mg{\cdot}kg^{-1}$). Furthermore, significant difference was found between the meadow chernozem and calcareous chernozem soil concerning their humus- (0.57 m/m%), AL-P_2O_5- (30 $mg{\cdot}kg^{-1}$) and total nitrogen content (331 $mg{\cdot}kg^{-1}$). The obtained significant differences among soil types show that it is necessary to perform the examinations per soil type during the evaluation of soil endowments, as the uniform evaluation of the examined area would neglect the differences that affect the efficiency of maize sowing seed production. Nevertheless, these characteristics change in each soil type, therefore, soil sampling has to be done individually per soil type, on the basis of a genetic soil map, performing on previously designated sampling points whose coordinates are known.

3.4. Examining the reliability of SPAD measurements

The SPAD value of the maize leaf increased from the basal part of the leaf-blade (41-42) to the 10-16 cm long distance (44-45) and then it started to decrease until the top of the leaf-blade (27-29) (*Figure 6*).

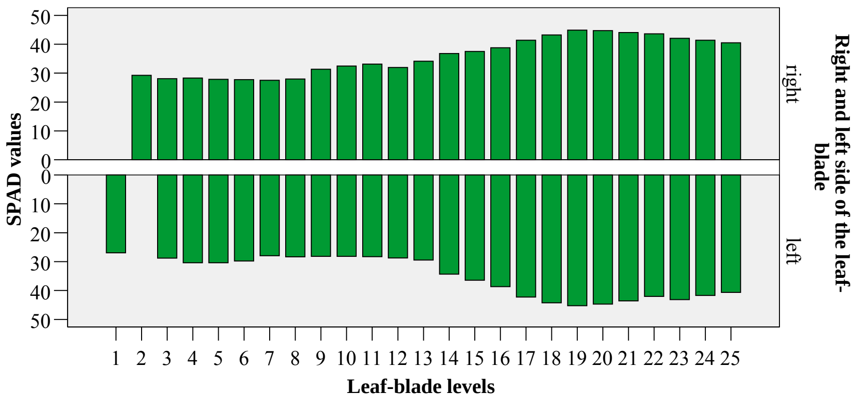

Figure 6. Changes in the SPAD values along the leaf

Considering the distribution of chlorophyll alongside the leaf-blade, I determined measurement methods consisting of 5, 10, 14, 20 and 30 measurement points. As for the 5 point measurement, I designated two points in the lower part and three points in the upper part of the leaf. In the case of the 10, 14, 20 and 30 point measurements, I set out the first two points on the right and left side of the leaf-blade's basal part and I distributed the rest along the right and left side of the leaf-blade proportionally.

Using the results of the 48 point measurements, I collated SPAD values in 30 replications per leaf in accordance with the 5, 10, 14, 20 and 30 point measurement methods.

I used regression analysis to evaluate the correlation of the number of measurement points and the average SPAD readings, the standard deviation within the leaf and between leaves. I obtained a weak correlation between the number of measurement points and the average SPAD values (R = 0.279), a strong one between the number of measurement points and the standard deviation within the leaf (R = 0.765) and an average correlation between the number of measurement points and the standard deviation between leaves (R = 0.570).

The determination of the method suitable for the detection of differences between leaves was done by variance analysis (ANOVA). Based on the data collated in 30 replications, I examined the differences between leaves in each replication and determined the value of F test statistics. Based on the average of F values, I evaluated the confidence level of the given measurement method in detecting the differences between leaves. The difference between the leaves can only be detected with an F value higher than 1. Also, the higher the F test statistics are, the higher the probability of being able to detect smaller differences is. As for the 5 point measurement method, the F value is lower than one, therefore, the differences between the leaves cannot strictly be detected. The F test provided a value higher than one in the case of the 10 point measurement method, therefore, the differences between the average SPAD values of leaves can only be reliably shown if at least the 10 point measurement method is performed. It is true in the case if we compare the values within leaves during the detection of differences between leaves. The detection of differences between leaves could also be done on the basis of the average SPAD values of leaves . In this case, it is enough to measure the SPAD values of leaves on five points, as the number of measurement points is affects the average SPAD value to a lesser extent.

3.5. Evaluating the heterogeneity of the sowing seed maize population

In the experimental area, the higher proportion of population patches was represented by the 80-90 cm high (37.9%) and the 70-80 cm high (28.6%) parts and the least frequent crop height categories were the 20-40 cm high (0.3%) and the 40-50 cm high (0.8%) patches. The territorial frequency of the 100-110 cm high (1.1%) and the 50-60 cm high (3.4%) population patches was also low. The ratios of 90-100 cm high (14.3%) and 60-70 cm high (13.6%) patches were nearly identical.

During the examination of the heterogeneity of the sowing seed maize population, I established that there was a close correlation between SPAD values and the number of grains per crop (grains•stem^{-1}) (R = 0.885), and between SPAD values and yield (g•stem^{-1}) (R = 0.896) (*Figure 7*).

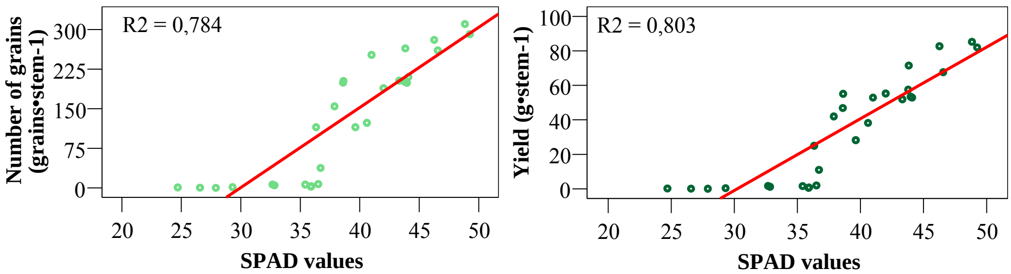

Figure 7. Correlation between the SPAD values, the number of grains per crop (grains·stem^{-1}) and yield (g·stem^{-1})

Based on the regression equations, taking SPAD values as a basis, I estimated the average grain number (grains·stem^{-1}) and yield (g·stem^{-1}) per plant height category, then I determined the accuracy of estimation by comparing the estimated values to the measured ones. The estimation of the number of maize grains and yield was inaccurate in populations shorter than 90 cm (60-87% and 59-89%), but it was accurate if the crops were taller than 90 cm (92-94% and 94-97%). Based on the SPAD readings, yield can be estimated, but the accuracy of estimation largely depends on the crop conditions. Crop conditions drastically change in heterogeneous populations, therefore, the yield estimation based on SPAD values can only be accurate in homogeneous populations.

The regression analysis showed a close correlation (R^2 = 0.668) between the SPAD values and the nitrogen content of leaves, too. The estimation of nitrogen content performed on the basis of the regression equation was accurate in all crop height category (89.4-99.6%) therefore, the accuracy of estimation was not affected by crop conditions.

I used main component analysis to search for the factors eliciting the heterogeneity of sowing seed maize population. Based on the main component weights, I established that there was a close correlation between the number of grains per crop (grains·stem^{-1}) (0.909), the nitrogen content (0.839) and zinc content of leaves (0.818). Potassium showed a weak correlation (0.314) and the other nutrients showed a very weak correlation (0.034-0.131) with grain number, nitrogen and zinc content. Yield (0.913) expressed in g·stem^{-1} also showed a close correlation with the nitrogen content (0.852) and zinc content of leaves (0.804) that was weakly affected by potassium (0.319) and very weakly affected by the other nutrients (0.035-0.139) (*Table 2*).

Table 2. Correlation between the grain number per crop (grains·stem^{-1}) and yield (g·stem^{-1}) and the nutrients taken up by the crop

	Main components	
Examined variables	**1**	**2**
N%	***0.839***	***0.852***
P%	-0.054	-0.053
K%	*0.314*	*0.319*
Mg%	0.113	0.118
Ca%	0.034	0.035
Cu mg·kg^{-1}	0.131	0.139
Zn (mg·kg^{-1})	***0.818***	***0.804***
Grain number (grains·stem^{-1})	**0.909**	-
Yield (g·stem^{-1})	-	**0.913**

Yield was also affected by the ratio of nutrients taken up by the crop. Based on the main component weights, grain number (grains·stem^{-1}) (0.836) had a strong correlation with P/Zn (-0.875), N/Cu (0.753) and N/P (0.716) proportions, whereas it had an average correlation with K/P (0.601) ratio and a weak one with the P/Cu ratio (-0.365). It showed a rather weak correlation with the other examined nutrients (0.009-0.233). Yield expressed in g·stem^{-1} (0.831) also showed a strong correlation with P/Zn (-0.866), N/Cu (0.752) and N/P (0.716) ratios, an average one with K/P (0.611) and a weak correlation with P/Cu (-0.365). Again, there was a very weak correlation between yield and the other nutrients (0.001-0.226).

During the evaluation of the correlations between grain number per crop, yield and the soil analysis results, it was shown that the heterogeneity in yield was caused by the heterogeneity in the zinc content of soil and the quantity of organic nitrogen in the soil. Besides the grain number (0.900), the zinc content of the upper 0-30 cm layer of soil and the quantity of organic nitrogen forms had a high main component weight (0.870; 0.830). Potassium (0.399) and $pH_{(H_2O)}$ (-0.470) showed a weak correlation with the number of maize grains (grains·stem^{-1}), whereas this correlation was very weak (0.022-0.125) concerning the other nutrients. Of the soil parameters in the 30-60 cm layer of soil, again, it was the zinc content (0.868) and the quantity of organic nitrogen forms (0.813) that showed close correlations with the grain number per stem (0.869). The system of correlations was weakly affected by inorganic nitrogen forms (0.325) and it was very weakly affected by the other soil parameters (0.120-0.290). Similarly to the grain number, of the soil analysis results of the upper 30 cm soil layer, yield expressed in g·stem^{-1} (0.883) showed a close correlation with zinc content (0.872) and the quantity of organic nitrogen forms (0.820), a weak correlation with potassium (0.391) and $pH_{(H_2O)}$ (-0.478) and a very weak one with the other nutrients (0.010-0.141). Of the examined soil parameters in the upper 30-60 layer, again, only zinc (0.877) and the organic nitrogen forms (0.817) showed close correlation with yield (0.835), which was weakly affected by the other examined soil parameters (0.129-0.291) (*Table 3*). The heterogeneity examinations showed that the efficiency of maize sowing seed production was basically restricted by the low zinc and organic nitrogen content of soils and it was slightly restricted by the disproportionate uptake of phosphorus and potassium.

Table 3. Correlation between the number of grain per crop (grains·stem^{-1}) and yield (g·stem^{-1}) with the soil analysis results

Soil depth (cm)	0-30		30-60	
	Main components		**Main components**	
Examined variables	**1**	**2**	**1**	**2**
$pH_{(H_2O)}$	*-0.470*	*-0.478*	-0.290	-0.291
Inorganic nitrogen forms (mg·kg^{-1})	-0.022	-0.047	*0.325*	0.287
Organic nitrogen forms (mg·kg^{-1})	***0.830***	***0.820***	***0.813***	***0.817***
AL-soluble phosphorus (mg·kg^{-1})	0.125	0.141	-0.120	-0.129
AL-soluble potassium (mg·kg^{-1})	*0.399*	*0.391*	0.139	0.153
Magnesium (g·kg^{-1})	0.043	0.043	-0.264	-0.269
Calcium (g·kg^{-1})	0.031	0.035	-0.149	-0.162
Copper (mg·kg^{-1})	-0.024	-0.010	0.141	0.163
Zinc (mg·kg^{-1})	***0.870***	***0.872***	***0.868***	***0.877***
Grain number (grains·stem^{-1})	**0.900**	-	**0.869**	-
Yield (g·stem^{-1})	-	**0.883**	-	**0.835**

The main component analysis showed a close correlation between the nitrogen content of leaves (0.811), SPAD values (0.913), the zinc content of the 0-30 cm layer of the soil (0.898) and the quantity of organic nitrogen forms (0.752), which was slightly affected by the $pH_{(H_2O)}$ (-0.353) and the potassium content of the soil (0.324).

Of the examined soil parameters in the upper 30-60 cm layer, zinc content showed a close correlation (0.725), whereas the quantity of organic nitrogen forms showed an average correlation (0.508) with the nitrogen taken up by the crop (0.919) and SPAD values (0.922) (*Table 4*).

Table 4. Correlations between SPAD values, the level of leaves' nitrogen supply and the soil analysis results of the upper 30-60 cm layer

	Soil depth (cm)	
Examined variables	**0-30**	**30-60**
$pH_{(H_2O)}$	*-0.353*	-0.258
Inorganic nitrogen forms ($mg \cdot kg^{-1}$)	0.087	-0.042
Organic nitrogen forms ($mg \cdot kg^{-1}$)	***0.752***	*0.508*
AL-soluble phosphorus ($mg \cdot kg^{-1}$)	0.087	-0.152
AL-soluble potassium ($mg \cdot kg^{-1}$)	*0.324*	0.132
Magnesium ($g \cdot kg^{-1}$)	-0.010	-0.106
Calcium ($g \cdot kg^{-1}$)	0.061	-0.067
Copper ($mg \cdot kg^{-1}$)	-0.030	0.151
Zinc ($mg \cdot kg^{-1}$)	***0.898***	***0.725***
Nitrogen content of leaves ($g \cdot 100g^{-1}$)	**0.811**	**0.919**
SPAD values	**0.913**	**0.922**

The variability in the nitrogen content of leaves and the SPAD values was caused by the heterogeneity in the zinc content of soils and the quantity of organic nitrogen forms. The research results clearly showed that zinc shortage is also shown through the nitrogen supply of leaves in the SPAD values in areas where the zinc content is inadequate, therefore, during the calculation of the nitrogen shortage based on the SPAD values and the fertiliser doses, one has to consider the effect of zinc shortage on SPAD values.

3.6. Efficacy of natural foliar fertilisers

In 2006, I used Natur Plasma in population treatment in 2.5% concentration (6.4 $l \cdot ha^{-1}$ with 250 $l.ha^{-1}$ water). As a result of the population treatment, the improvement of grain number in comparison with the control was 59 $grains \cdot stem^{-1}$ on average, whereas yield increased by 14.2 $g \cdot stem^{-1}$ (0.9 $t \cdot ha^{-1}$). There was a significant difference between the control and the treated population.

In 2007, I performed population treatment with Natur Plasma and Natur Plasma enriched with zinc in 2.5% concentration (6.4 $l \cdot ha^{-1}$, with 250l water), with Amalgerol Premium in 1.0% concentration (2.5 $l \cdot ha^{-1}$, with 250 $l \cdot ha^{-1}$ water) and 250 $g \cdot ha^{-1}$ Natur Vita (with 250 $l \cdot ha^{-1}$ water). As for stubble-field treatment, I applied Amalgerol Premium in 2.0% concentration (6.0 $l \cdot ha^{-1}$, with 300 $l \cdot ha^{-1}$ water) and Natur Plasma in 3.2% concentration (10 $l \cdot ha^{-1}$, with 300 $l \cdot ha^{-1}$ water). During the statistical evaluation of yield, the yield increasing effect of the different natural foliar fertilisers (Natur Plasma, Amalgerol Premium) was not shown. The foliar fertilisers applied at the 5-8 leaf stage and before tasselling (Natur Plasma, Natur Plasma enriched with zinc, Natur Vita, Amalgerol Premium) resulted in an improvement of 41-84 $grains \cdot stem^{-1}$ in the grain number and 5.4-11.9 $g \cdot stem^{-1}$ (0.3-0.7 $t \cdot ha^{-1}$) in yield. There were significant differences between the control and the population treatments.

In 2008, I used the 2.5% dose of Natur Plasma (6.4 $l \cdot ha^{-1}$, with 250 $l \cdot ha^{-1}$ water), 1.0% dose of Amalgerol Premium (2.5 $l \cdot ha^{-1}$, 250 $l \cdot ha^{-1}$) and 250 $g \cdot ha^{-1}$ dose of Natur Vita in population treatment. Amalgerol Premium (5.0 $l \cdot ha^{-1}$) (09/06/2008), and Natur Plasma (5.0 $l \cdot ha^{-1}$) (07/07/2008 and 21/07/2008) were applied in combined treatment. Based on the results of 2008, the examined products resulted in 2.6-5.5 increase in SPAD readings, 9-39 $grains \cdot stem^{-1}$ increase in grain number and 8.1-11.3 $g \cdot stem^{-1}$ (0.5-0.7 $t \cdot ha^{-1}$) yield surplus in comparison with the control. There were significant differences between the control and the population treatments.

The average 14 hour long atmospheric humidity during the period of pollen spread (July) was 46% in 2006, 44% in 2007 and 59% in 2008. The smallest measured value was between 26-35%, whereas the biggest one was between 78-93%. In July, the number of days of relative humidity less than 45% was the highest in 2006 and 2007 (19-21 days), that is, as regards grain number per crop, 2006 and 2007 were less favourable than 2008. It follows from the results of grain number and yield that the examined products are able to counterbalance the yield reduction effect of precipitation shortage and atmospheric drought if they are applied at the 5-8 leaf stage and one-one and a half weeks before tasselling in population treatment.

4. NEW AND NOVEL SCIENTIFIC RESULTS OF THE THESIS

- In the soil genetic system, there can be soil-related differences between soil types that are close to each other that affect the way of nutrient replenishment, therefore, it is practical to provide fertilisation technical advice in relation to the soil types that can be found on the plot.
- During the last 40 years, the humus content of the soil in the region of Hajdúszoboszló decreased to an extent that restricts the efficiency of agriculture.
- Based on the SPAD value distribution along the leaf-blade, I identified a systematic measurement method to show the differences in SPAD values between crops.
- Based on the measurement of crop height, I developed a method for the examination of crop population heterogeneity.
- I showed that the efficiency of maize sowing seed production in the region of Hajdúszoboszló is most affected by the zinc content of soil and the quantity of organic nitrogen forms.
- Based on the analysis of correlations between the average SPAD values of leaves, their nitrogen content and the soil analysis results, I showed that zinc shortage is also shown through the nitrogen supply of leaves in the SPAD values in areas where the zinc content is inadequate.
- I determined an examination method for the evaluation of the foliar fertiliser field experiments, during which I established that the foliar fertilisers Natur Plasma, Natur Vita and Amalgerol Premium, if applied at the 5-8 leaf stage and one-one and a half weeks before tasselling, have a favourable effect on the yield and grain number per plant of sowing seed maize population. The examined products are able to counterbalance the yield reduction effect of precipitation shortage and atmospheric drought if they are applied at the 5-8 leaf stage and one-one and a half weeks before tasselling in population treatment.

5. PRACTICAL USEFULNESS OF RESULTS

- The method of examining population heterogeneity is suitable for the identification of soil parameters that restrict yield.

- The improvement of areas that contains inadequate amounts of zinc has been started on the examined field.
- The products Natur Plasma and Natur Vita were officially authorised due to the technology tested by me.

6. Publications In The Subject Matter Of The Thesis

Ángyán J. – Menyhér Z.: 1988. Integrált alkalmazkodó növénytermesztés. GATE – KSZE, Gödöllő - Szekszárd.

Kádár I.: 1992. A növénytáplálás alapelvei és módszerei. Magyar Tudományos Akadémia - Talajtani és Agrokémiai Kutatóintézet, Budapest.

Láng I. – Csete L.: 1992. Az alkalmazkodó mezőgazdaság. Agricola Kiadói és Kereskedelmi Kft., Budapest.

Loch J.: 1999. A környezetkímélő tápanyag-gazdálkodás elvei. [In: Füleky Gy. (szerk.) Tápanyag-gazdálkodás.]. Mezőgazda Kiadó, Budapest, 228-230.

Németh T.: 1995. Gondolatok a tápanyaggazdálkodásról a fenntartható mezőgazdasági fejlődés tükrében. [In: XXXVII. Georgikon Napok Kiadványa. 1995. szeptember 14-15., I. kötet.]. PANNON ATE, Keszthely, 101-109.

Németh T.: 2001. A tápanyag-gazdálkodás szerepe a szántóföldi növénytermesztésben. [In: Kovács F., Kovács, J., Bancerowski, J.-né (szerk.) Lehetőségek az agrártermelés környezetbarát fejlesztésében.]. Magyar Tudományos Akadémia, Agrártudományok Osztálya, Budapest, 106-132.

Németh T. – Várallyay GY.: 1998. A trágyázás és tápanyag-utánpótlás jelenlegi helyzete és lehetőségei. Agrofórum. 9. 13: 2-4.

Pepó P.: 2007. A kukorica (*Zea mays* L.) termesztés ökológiai feltételeinek és agrotechnikai elemeinek értékelése. Acta Agronomica Óváriensis. 49. 2/1: 169-175.

Ruzsányi L. – Pepó P.: 1999. Növénytermesztés és környezet minőségének összefüggései. [In: Ruzsányi L., Pepó P. (szerk.) Növénytermesztés és környezetvédelem.]. Magyar Tudományos Akadémia - Agrártudományi Osztály, Budapest, 10-18.

Sárvári M.: 1998. A termesztési tényezők hatása a kukorica termésére. Növénytermelés. 47. 2: 213-221.

Szabó L.: 1999. A tápanyagellátás környezeti vonatkozásai. [In: Füleky Gy. (szerk.) Tápanyag-gazdálkodás.]. Mezőgazda Kiadó, Budapest, 675-695.

Szász G.: 1997. Az éghajlatváltozás és a fenntartható gazdaság kapcsolata a Nagyalföldön. [In: Rakonszai J., Tímár J. (szerk.) Alföldi Tanulmányok 1997 XVI.]. Nagyalföld Alapítvány, Békéscsaba, 35-50.

Szász G.: 2002. A klimatikus természeti erőforrások hasznosulása a hazai növénytermesztésben. Agrártudományi Közlemények - Acta Agraria Debreceniensis. 9: 101-106.

Várallyay Gy.: 2001. Szemléletváltozások a magyarországi talajjavítás történetében. Agrokémia és Talajtan. 50. 1-2: 109-136.

7. LIST OF THE SCIENTIFIC COMMUNICATION PUBLISHED IN THE PROFESSIONAL FIELD OF THE DISSERTATION

Scientific publication in Hungarian reviewed journal:

Víg R.–Dobos A.: 2006. Tápanyag-vizsgálati adatok összehasonlító vizsgálata különböző adottságú mintaterületeken. Agrártudományi Közlemények - Acta Agraria Debreceniensis. 22. Különszám: 85–90. HU–ISSN 1587–1282

Víg R.–Dobos A.–Pongrácz Z.: 2007. A precíziós tápanyag-utánpótlást megalapozó talajvizsgálatok Hajdúszoboszló térségében. Agrártudományi Közlemények - Acta Agraria Debreceniensis. 26. Különszám: 141–148. HU–ISSN 1587–1282

Víg R.–Dobos A.–Pongrácz Z.: 2008. Csernozjom talajok talajvizsgálati eredményeinek összehasonlító statisztikai értékelése. Agrártudományi Közlemények - Acta Agraria Debreceniensis. 30. Különszám: 93–99. HU–ISSN 1587–1282

Scientific publication in an English language reviewed Hungarian journal:

Víg R.–Dobos A.–Pongrácz Z.: 2008. Comparative examination of meadow and chernozem soils on the Hajdúság loess ridge. Cereal Research Communications. 38. Suppl.: 1887–1890. ISSN 0133–3720

Dobos A.–Víg R.–Pongrácz Z.: 2008. Evaluation of the soil examination results of Békés and Hajdúság crop lands. Cereal Research Communications. 38. Suppl.: 1875–1878. ISSN 0133-3720

Non-rewiewed conference proceedings in Hungarian:

Dobos A.–Víg R.–Pongrácz Z.: 2006. Környezetkímélő tápanyag-gazdálkodást megalapozó kutatások a Tiszántúlon. [In: Baranyi B.–Nagy J. (szerk.) Területfejlesztés, Agrárium és Regionalitás Magyarországon.] Debreceni Egyetem Agrártudományi Centrum és Magyar Tudományos Akadémia Regionális Kutatások Központja, Debrecen. 315–328. ISBN 963–9052–67–1

Víg R.–Dobos A.–Pongrácz Z.: 2006. A talajheterogenitás vizsgálata a hajdúsági löszháton. [In: Nagy J.–Dobos A. (szerk.) Környezetkímélő növénytermesztés - minőségi termelés.] Debreceni Egyetem Agrártudományi Centrum, Debrecen. 186–195. ISBN 978–963–9732–09–4

Víg R.–Dobos A.–Pongrácz Z.: 2008. Hajdúsági csernozjom és réti talajok tápanyag-ellátottságának statisztikai értékelése Hajdúszoboszló térségében. [In: Baranyi B.–Nagy J. (szerk.) Regionalitás, területfejlesztés és modernizáció az észak-alföldi régióban.] Debreceni Egyetem Agrár- és Műszaki Tudományok Centruma és Magyar Tudományos Akadémia Regionális Kutatások Központja, Debrecen. 351–359. ISBN 978–963–9732–24–7

Dobos A.–Víg R.–Pongrácz Z.: 2009. A növényállomány heterogenitásának értékelése beltenyésztett kukoricavonalon. [In: Baranyi B..–Nagy J. (szerk.) Tanulmányok az agrár- és a regionális tudományok köréből az Észak-alföldi régióban.] Debreceni Egyetem Agrár- és Műszaki Tudományok Centruma és Magyar Tudományos Akadémia Regionális Kutatások Központja, Debrecen. 215–226. ISBN 978–963–9899–10–0