Thesis of doctoral (PhD) dissertation

PRODUCTION TECHNOLOGICAL INVESTIGATION OF SOYBEAN VARIETIES AND SPECIFIC - PLACE OF PRODUCTION DEVELOPMENT

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1. BACKGROUND AND OBJECTIVES OF THE DOCTORAL DISSERTATION

Serving the needs of an accelerated world is always a challenge, no matter what area we investigate. However, agriculture is a segment that is not always able to meet the increased needs immediately. Such is the increased need for protein in the processing, feed and food industries. The range of protein crops that can grow in Hungary is very wide, but for the three large users mentioned above, certain protein crops are of paramount importance. Such is the case of soybeans, which thanks to the special protein compounds (amines) and their oil content, have been incorporated into the production of domestic products and have now grown into an indispensable raw material.

Like most European countries, Hungary meets its needs mainly from imports, despite the fact that since 2015 soybean production is experiencing a renaissance again. In order to reduce foreign imports of soybeans in Hungary, new measures became necessary, which the Hungarian government made available to producers in the form of subsidies. As a result, the sown area of soybeans increased spectacularly in 2015 (72,016 ha), but the change in area was not accompanied by increase the yield. However, in 2016, only those producers remained who developed a own production system and cultivation technology that allowed them to successfully use soybeans in their crop rotation. Although the sown area decreased by 16% in that year, the average yield improved (3.03 t ha^{-1}) (HTTP4). The continuous changes in the protein crop program visibly affects well the mood of domestic producers. In 2017, the area under soybeans increased again, and even exceeded the area of 2015 by more than 2,000 hectares, but the average yield was 2.37 t ha^{-1}, which was well below at the 2016 result. This increase in area and low average yield was partly due to soybeans produced as an intermediate crop, from which most farmers wanted to profit, however, the yield of super early varieties in Hungary was very low during this period (<1 t ha^{-1}), so the average soybean yield did not improve.

Despite extreme weather factors, domestic weather generally creates optimal conditions for agricultural production. Our good endowments enable high quality soybean production. Based on the domestic "production motto", soybeans are grown where corn can cultivable safely. Many question the suitability of soybeans for crop rotation, because Hungary cannot be considered the best maize and soybean growing zone, but the yields they were never left behind the desired 1500-2000 kg ha^{-1} (BALIKÓ and FÜLÖPNÉ, 1997).

Over the next 50 years, the frequency and severity of current weather anomalies will increase (FÜHRER et al., 2013; MOLNÁR and GÁCSER, 2014), which will also affect the amount of precipitation and that means that not only the intensity and distribution will change in the near future, but also most likely the size of the quantity (LÁNG et al., 2007; AINSWORTH and ORT, 2010). This unpredictable distribution and increase in average temperature will only benefit certain soybean varieties in the future. The primary factors in soybean production are the amount of heat, which alternates between 2000 and 2700 ° C (depending on the variety and ripening group) and the amount of precipitation. Although the kind of supply are expanding year by year and more and more varieties are available that tolerate the arid climate well, during the flowering-, sleeve and core binding periods, all soybean varieties require a minimum rainfall of 180-250 mm. In the absence of this, most of the time experienced yield losses (ZANON et al., 2016; MATIU et al., 2017). Although the increasingly frequent drought summers in Hungary are not conducive to the cultivation of soybeans, it possible to defend against it well by irrigation, which the current domestic agricultural subsidies and projects provide to more and more farmers.

The current soy assortment has such a wide range in Hungary that it profitable to produce in all 19 counties. The demand for seeds of GMO-free soybeans and varieties is very high, so it will necessary to include even more crop rotations in the future. The Hungarian statistical analyses confirm that increasing the area does not always lead to increase in yield, so the analysis of the choice of variety - microclimate - agrotechnology and then the cultivation technologies built on them are much more pronounced in this culture than as with well-known industrial plants.

1.1. OBJECTIVES

The soybean (Glycine max) is an herbaceous, annual crop belonging to the legume family that lives in symbiosis with the so-called *Bradyrhizobium japonicum* bacterium, which is able to bind atmospheric or biological nitrogen (BNF) during the entire vegetation process needs (CHU et al., 2016). The necessary nodule for nitrogen fixation are formed by the bacterium on the main and secondary roots through a special develops, if all the conditions are given for the process, because in fact this bacterium is not native in the domestic soils, so the soybean seeds should be inoculated. However, the current producer society does not cover needs of the plant, but also was incorrectly into the public consciousness due to yield-increasing effect aply the inoculation of the seed- or the soil with bacteria.

That is why I started to deal with the domestic problems of soybean production, their exploration and possible solutions. Based on foreign samples, it can be stated that soybeans are excellently grown in the Pannonian Biographical Region and only a complex approach is needed to improve them. Most of the Hungarian growing areas where soybeans are grown are well-structured, brown-forest, chernozem, meadow and moulding soils. Proper varietal selection, sowing time, seed rate, seed or soil inoculation, row spacing, additional treatments until stocking closure or flowering, such as chemical and / or mechanical weeding, foliar fertilization, protection against pathogens and pests, and irrigation, all contribute to for successful cultivation technology.

My Ph.D. (doctoral) dissertation was prepared on the basis of soy experiments carried as an employee of Lajtamag Kft. and Hédervári FMG Nonprofit Kft. between 2016-2018, which were set up in two counties and several locations.

The main objectives of my research are the following, which I examined in the two most popular ripening groups (very early and medium ripening soybean varieties):

- Examination of a soil inoculation preparation using soybean varieties belonging to the very early and middle ripening maturity group used in the experiment.
- Evaluation of the effect of row spacing with three different soybean cultivars and the lowest seed standard for each cultivar.
- Analysis of the effect of different suspension and powder inoculants on the seed surface with the ES Mentor soybean variety belonging to the very early ripening group.

- Analysis of combinations of different dressing and inoculants that can be applied to the seed surface and the application of dressings with the ES Mentor (very early ripening group) soybean variety.
- Investigation of the effect of foliar fertilizer treatments on the yield and content indices of the studied soybean variety (ES Mentor).
- Investigation of the effect of the minimum (30 mm) and maximum (60 mm) dose of irrigation water used for the production of soybean in the region of Western Hungary with the ES Mentor indicator plant.
- Investigation of the effects of site-specific soybean production on the basis of data series for three years (2016-2018) (effects of tillage, irrigation, precipitation and temperature on the average yield, protein and oil content of the studied varieties).

2. MATERIAL AND METHOD

Our research we are done two counties to study the specific effects of different production areas and the effects with related agrotechnologies (2016-2018).

The study sites were as follows:

- Győr-Moson-Sopron County,
- Baranya county.

The characteristics of the offered areas are that they belong to the II. categories of arable land, they have good water, air and heat management, but their ability to provide nutrients is influenced by the lime content of the soil, so the vintage effect may be more pronounced. In general, they are moderately or well supplied with nitrogen, potassium and phosphorus. The pH of the experimental areas ranged from neutral (pH 6.8-7.2) to weakly acidic (pH 5.5-6.8).

Bóly (2016, 2017, 2018)

Semi-farm conditions (0.5 ha / treatment) were studied with a medium-ripening soybean variety (Steara) with a one-component soil inoculant product containing only the bacterial strain *Bradyrhizobium japonicum*, irrigated (30 mm) and non-irrigated conditions,how it can help the development of the plant population during the three years, the different agronomically important periods, such as the flowering, sleeve- and core binding periods, and what conditions are needed to exert its positive effect as well as the yield growth.

Mosonudvar (2016,2017,2018)

1. The experiment with a soil inoculant preparation only the bacterial strain *Bradyrhizobium japonicum* was also set up in this area under non-irrigated and irrigated (semi-industrial - 0.5 ha^{-1} / treatment) conditions, however, a very early (ES Mentor) soybean variety was used for safe harvesting.
2. Our other study in this area was the irrigation experiment studied over three years, with two different amounts (30- and 60 mm), also using the ES Mentor soybean variety as an indicator plant. The objectives of our analyses included the determination of test results such as:
    - the significant difference in the height, node number, SPAD value, number of pods and seeds of the two treatments,
    - how much yield differences develop between the two irrigation waters compared to the control and each other,
    - increases or not the oil or protein content of one dose of irrigation.

Hédervár (2016, 2017, 2018)

Different studies were performed under small plot conditions to determine how the results change under the influence of technological elements such as:

change in yield of soybean cultivars grown with different row spacing (ES Mentor, Sy Eliot, Steara) examined in the context of the lowest seed norm * row spacing (2016),

application of different seed inoculants in Hungarian soybean production and their effects on the studied parameters (nodule number, plant height, pod height, pod and seed number) of the soybean variety used in the experiment (ES Mentor), as well as on its yield, oil- and protein content (2017),

and the use of two ipcosanol dressings (Rancona 15ME and Rancona i-MIX) in combination with or without different inoculants, measuring the factors listed for inoculants (2017),

Application of two different of foliar fertilizer formulations in two different periods for yield increase and by examining and analysing changes in treatments in nodule number, height, node number, pod and seed number (2018).

3. RESULTS

Test results of experiments with the soil inoculant preparation of the bacterial strain *Bradyrhizobium japonicum* (2016-2018)

Experiments with the soil extinguishing preparation containing the bacterial strain Bradyrhizobium japonicum were set up at two sites for three years (2016-2018) and we tested the ES Mentor variety in Mosonudvar and the Steara variety in Bóly under semi-industrial conditions every year.

Based on our studies, the preparation did not help the formation of nodulation (irrigated or non-irrigated conditions) at any of the experimental sites, therefore the possibility of solving the issues and problems related to this parameter requires further research. During the three (2016, 2017, 2018) years, we found that the plant height of the stand treated with the non - irrigated soil preparation was continuously lower than the irrigated stand by 6,1-9,7 centimetres on average, which differences often proved to be significant differences in the studies (*2016.* year ES Mentor $SzD_{5\%}$ 5,2 cm, Steara $SzD_{5\%}$ 8,5 cm, in *2017.* year ES Mentor $SzD_{5\%}$ 3,5 cm, Steara $SzD_{5\%}$ 9,8 cm, in *2018.* year ES Mentor $SzD_{5\%}$ 5,0 cm, Steara $SzD_{5\%}$ 9,2 cm).

In the study of the SPAD value, we analysed (2016–2018) how the soil inoculant preparation used in the experiments affected the chlorophyll content of the plants during the pods bonding period [BBCH (70–75)]. In 2016 and 2018, we found a significant difference between non-irrigated and irrigated treatments as a result of soil inoculation (in 2016 ES Mentor $SzD_{5\%}$ 1,7 SPAD, Steara $SzD_{5\%}$ 2,9 SPAD; in 2017 ES Mentor $SzD_{5\%}$ 3,7 SPAD , Steara $SzD_{5\%}$ 2,3 SPAD, in 2018 ES Mentor $SzD_{5\%}$ 2,3 SPAD, Steara $SzD_{5\%}$ 2,3 SPAD), based on the results in 2016 6,4 – 9,7% -; in 2018 we measured 7,1 – 8,6% higher chlorophyll content in the case of irrigated plant population, while in 2017 the treatments showed only a significant difference compared to the control treatment, which varied between 3,1 and 6,6 SPAD.

In the examination of the pod numbers we experienced that in the areas treated with the soil inoculation composition containing the bacterial strain Bradyrhizobium japonicum, on average (2016) *10,7* -, (2017) *9,6* -, (2018) *12 , 7* pods under irrigated and irrigated conditions compared to the control treatment, which tended to differ significantly in 2016 (ES Mentor $SzD_{5\%}$ 7,8 piece, Steara $SzD_{5\%}$ 9,5 piece) and 2018 (ES Mentor $SzD_{5\%}$ 9,8 piece, Steara $SzD_{5\%}$ 8,8 piece), while in 2017 the statistical analysis showed no verifiable difference.

Examining the seed numbers, we found that in most cases they were formed in proportion to the pod's numbers. For the two soybean variates, we still found a significant difference between irrigated and non-irrigated treatments in 2016 (ES Mentor 10,8 -; Steara 9,8 seed difference), in 2017 (ES Mentor 9,6 -; Steara 8,1 pieces seeds difference) and in 2018 (ES Mentor 7,2 -; Steara 10,5 pieces seeds difference), while they showed a more significant difference compared to the control (we measured in 2016 12%-, in 2017 13%- and in 2018 10% less soybeans), based on which we concluded that no increase in yield is expected as a result of the soil inoculant.

The soil inoculant product tested in 2016 increased the yields of irrigated plants on average by 387 kg ha^{-1}, while the average yield of the compared non-irrigated experimental areas was significantly lower (ES Mentor $SzD_{5\%}$ 249 kg ha^{-1}, Steara $SzD_{5\%}$ 262 kg ha^{-1}). Yields measured in 2017 were similar for both varieties as in 2016. Significantly fewer soybeans were harvested from arable land treated with the soil inoculant compared to the control treatments (ES Mentor $SzD_{5\%}$ in 2017 226 kg ha^{-1}; Steara $SzD_{5\%}$; 208 kg ha^{-1}), while irrigation improved yields with 7,2%. The experiments carried out in 2018 achieved higher yield averages, however, considering their tendency, it was also observed that we measured significantly weaker yields on soils treated under non-irrigated conditions, which were on average 325 kilograms lower than irrigated stands. The results also showed that with the bacterial strain Bradyrhizobium japonicum soil inoculant used in the experiment, we could not achieve higher yields during the three years (Table 1).

Table 1. Yield averages of soybean varieties used in the soil inoculant experiment under irrigated and non-irrigated conditions (Mosonudvar, Bóly, 2016-2018)

Average yield kg ha^{-1}	Mosonudvar				Bóly			
	ES Mentor-irrigated – soil inoculant	Control – irrigated	ES Mentor-non-irrigated - soil inoculant	Control - non-irrigated	Steara-irrigated – soil inoculant	Control - irrigated	Steara- non-irrigated - soil inoculant	Control - non-irrigated
2016. year	3275	3450	2850	3100	3050	3350	2700	3000
2017. year	3150	3400	2850	3100	3125	3300	2800	3050
2018. year	3350	3625	3000	3300	4025	4200	3700	3900

Examining the results of protein and oil contents, we found that in 2016 based on the analyses, that the protein value of soybeans treated with irrigated and soil inoculated products differed by 0,6% from the values measured under inoculated and non-irrigated conditions, and 3,7% higher values measured for treated irrigated soils in terms of trend in oil content. In 2017, irrigation again had a positive effect on soil inoculation, resulting in an average 0,6% increase in protein content and 0,9% higher oil contents compared to non-irrigated treatments. In 2018, we found that the protein index improved by 0,3% for irrigated (inoculant soil) areas, while for the oil content were by 0,9% lower each soybean varieties under non-irrigated condition on treated soils, while under the influence of irrigation improved by an average value of 0,8% for both varieties (Table 2).

Table 2. Protein- and oil content results of soybean varieties used in the soil inoculant experiment, under irrigated and non-irrigated conditions (Mosonudvar, Bóly, 2016-2018)

Protein- and oil content, %	Mosonudvar								Bóly							
	ES Mentor-irrigated – soil inoculant	Control – irrigated	ES Mentor-non-irrigated - soil inoculant	Control - non-irrigated	Steara-irrigated – soil inoculant	Control - irrigated	Steara-non-irrigated - soil inoculant	Control - non-irrigated	ES Mentor-irrigated – soil inoculant	Control – irrigated	ES Mentor-non-irrigated - soil inoculant	Control - non-irrigated	Steara-irrigated – soil inoculant	Control - irrigated	Steara-non-irrigated - soil inoculant	Control - non-irrigated
	Protein, %	Oil, %	Protein, %	Oil, %	Protein, %	Oil, %	Protein, %	Oil, %	Protein, %	Oil, %	Protein, %	Oil, %	Protein, %	Oil, %	Protein, %	Oil, %
2016. year	31,4	21,5	31,6	21,7	30,8	20,7	31,4	20,9	31,4	21,6	31,7	21,8	30,8	20,9	31,4	21,1
2017. year	31,3	21,4	31,6	21,7	30,7	20,6	31,3	20,9	31,2	21,3	31,7	21,6	30,6	20,7	31,2	21
2018. year	31,3	21,5	31,5	21,9	30,9	20,7	31,2	21,1	32,7	21,9	33,3	21,9	32,4	20,9	32,9	21,2

Further analysing our results with Pearson's correlation, we found that inoculation * irrigation had a moderate effect on the SPAD value (0,370 **), number of pods (0,367 **), number of seeds (0,327 **), the yield (0,438 **) and the oil content (0,384 **) of the soybean varieties used in the experiment, while no similar correlations could be detected in the analyses for the soil extinguisher applied without irrigation (Table 3).

Table 3. Effect of soil inoculant preparation* irrigation and soil inoculant preparation (without irrigation) on the studied parameters of soybean varieties used in the experiment, analysed by Pearson's correlation

	Plant height, cm	Number of nodes, pcs.	SPAD-value	Number of pods, pcs.	Number of seeds, pcs.	Averageyield, kg ha^{-1}	Protein content, %	Oil content, %
Soil inoculant * irrigation	0,170	0,214	**0,370****	**0,367****	**0,327****	**0,438****	0,179	**0,384****
Soil inoculant	0,175	0,194	0,057	0,100	0,178	0,189	-0,066	0,146

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Test results for row spacing (24-, 48- and 75 cm) applicable in soybean production

Three soybean varieties were included in the study that studied the different effects of selected row spacing with the low seed ratio increasingly used in practice, which were 500,000 germ ha^{-1} for ES Mentor, 550,000 germ ha^{-1} for Sy Eliot, and 450,000 germ ha^{-1} for Steara. In addition to the yield, we also examined the agronomically highlighted periods, parameters and protein - oil contents.

Analysing the plant height results, we found that in the case of the ES Mentor and Sy Eliot varieties a favourable stand height developed at the 24 cm row spacing, while for Steara varity two row spacing (24- and 75 cm row spacing) proved to be optimal.

Examining the development of SPAD values, we found that the value of ES Mentor measured on 75 cm row spacing was outstanding (42,8), while in the case of Sy Eliot we did not get a similar difference, because the SPAD values of all three row spacing showed very close values, while in the case of the Steara variety the highest SPAD values (43,2) were measured on the row spacing of 75 cm compared to the two row spacing, on the basis of which we established that that small differences between the rows (ES Mentor: 1,2 to 1,4 SPAD; Sy Eliot: 0,1 to 0,5 SPAD, Steara: 2,1 to 2,4 SPAD) suggest that row spacing does not affect the chlorophyll content of plants during vegetation.

Based on the results of the examination of the number of sleeves, we established that the number of sleeves measured by ES Mentor and Sy Eliot was 6 pods less on the row spacing 48 cm, than the number of sleeves measured on the row spacing of 24- and 75 cm, while we measured quantities 20% higher than Steara on a row spacing of 75 cm compared to both row spacing, however, based on the results of the statistical analyses, a significant difference was observed only in the Steara variety (ES Mentor $SzD_{5\%}$ 8,2 pcs, Sy Eliot $SzD_{5\%}$ 8,0 pcs, Steara $SzD_{5\%}$ 7,5 pcs). Based on the results of the number of seeds, we established that ES Mentor gave 14% higher seed number on row spacing of 24 cm and Steara had 13% higher seed on row spacing 75 cm compared to the other two row spacing, while we did not obtain outstanding results for Sy Eliot variety.

After harvest, we experienced that in the case of the ES Mentor variety, a row spacing of 24 cm proved to be the most appropriate, which was also confirmed by the average yield (4140 kg ha^{-1}).

For the Sy Eliot variety, higher or more prominent values were measured within a row spacing of 24 cm during the whole study period, which was also confirmed by the 13,3% higher yield average (3960 kg ha^{-1}). In the case of the Steara variety, the row spacing of 75 cm showed better results for the parameters examined from the flowering period and this was also confirmed by the yield (4230 kg ha^{-1}). During the statistical analysis, the highlighted yields also differed significantly from the examined row spacings (Figure 1).

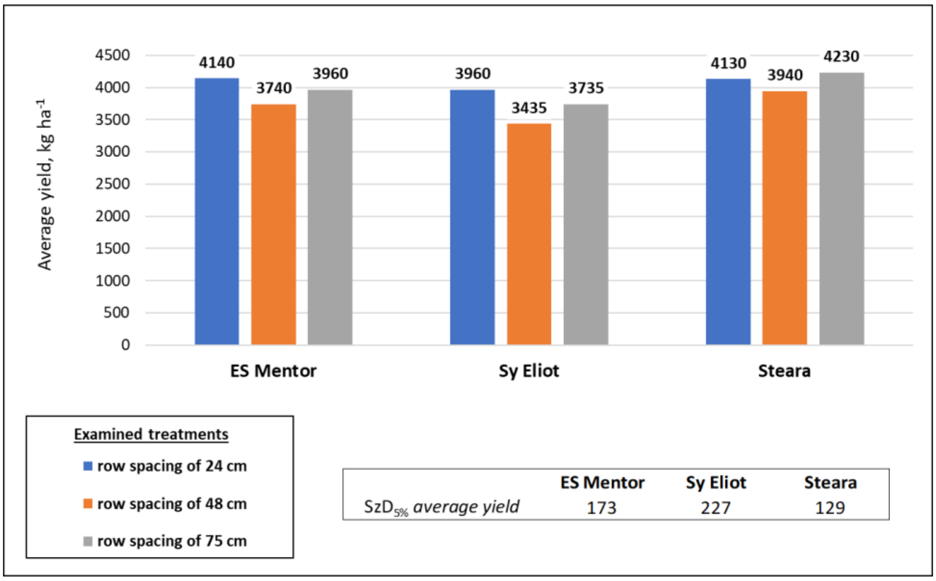

Figure 1. Yield averages of the soybean varieties used in the experiment at the examined (24-, 48-, 75 cm) row spacing, under small plot conditions (Hédervár, 2016)

Analysing the oil and protein values, we experienced that the outstanding protein and oil content did not always correlate with the highest yield of the varieties used in the study. We measured the highest protein value (32,0%) of ES Mentor and Sy Eliot on the row spacing of 48 cm, while Steara variety had the best protein content (31,0%) on the row spacing of 75 cm. Based on the results of the oil content measurements, the lowest value was gotten for the ES Mentor on row spacing of 48 cm (19,8%), while were measured on the row spacing of 75 cm for the Sy Eliot variety the best oil values (21,4%), while a similar trend was obtained for the Steara variety as for the ES Mentor (Table 4).

Table 4. Results of protein and oil content of soybean varieties used in the experiment, at the examined (24-, 48-, 75 cm) row spacing, under small plot conditions (Hédervár, 2016)

Protein- and oil content, %	ES Mentor		Sy Eliot		Steara	
	Protein, %	Oil. %	Protein, %	Oil. %	Protein, %	Oil. %
Row spacing of 24 cm	30,9	20,5	31,5	20,9	30,2	20,0
Row spacing of 48 cm	32,0	19,8	32,0	20,0	30,1	20,0
Row spacing of 75 cm	31,1	20,5	30,3	21,4	31,0	19,8

We further analysed the results with Pearson's correlation, based on which we experienced that the line spacing only affected the height of the Sy Eliot variety, for which there was a strong negative (-0,688 **) relationship in the analysis, while in the development of the SPAD value in two varieties - ES Mentor and Steara - we experienced that the row spacing with medium strength (0,315 **; 0,482 **) affected the values. In the case of the development of the numbers os sleeves, can only be verified at ES Mentor with a negative medium strength (-0,496 **), that the measured result was indeed higher due to row spacing. In the case of outstanding ES Mentor and Steara varieties for number of seeds, the degree of row spacing influence showed a negative very strong (-0,756 **) and a medium strength (0,401 **) relationship, on the basis of which we established, that the optimal row spacing of the ES Mentor variety is 24 cm-, while that of the Steara variety is 75 cm if we want to produce with the lowest seed rate. Yields for all three varieties, we obtained a negative medium strength (0,444 **; 0,424 **; 0,331 **) relationship, according to which row spacing does indeed have an effect on yield development. The last examined parameter were the content indices (protein and oil), which were not affected by the row spacing based on the analysis, because low r-values were obtained in all cases (Table 5).

Table 5. The degree of correlation of row spacing * soybean variety to the parameters examined in the experiment, analysed by Pearson's correlation (Hédervár, 2016)

	Plant height, cm	Number of nodes, pcs.	SPAD-value	Number of pods, pcs.	Number of seeds, pcs.	Averageyield, kg ha^{-1}	Protein content, %	Oil content, %
ES Mentor*row spacing	0,106	0,087	**0,315***	**-0,496***	**-0,756***	**0,444***	0,071	0,034
Sy Eliot*row spacing	**0,688***	**0,353***	**0,336***	**-0,409***	**-0,442***	**0,424***	0,153	0,162
Steara*row spacing	0,169	0,052	**0,482***	**0,297***	**0,401***	**0,331***	0,212	0,131

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Test results of the effect of different soy inoculants

Among the inoculant used in the study the Blue Seed - better known as Iregi inoculant - dissolved from a powder, while Serbian inoculant (Signum and NS) were applied as a suspension (concentrate) on the ES Mentor soybean seed 21 days before sowing. The study were conducted under small plot conditions in four replicates in 2017 to exclude externalities as much as possible.

Examining the effect on nodulating, we experienced that not only the control (uninoculated seed) but also the three different (Blue Seed, Signum, and NS) inoculants did not nodulated during the flowering period [BBCH (60–66)].

Later, in the sleeve period [BBCH (69-75)], the double-dose Blue Seed inoculant improved nodulation (average 1 nodulate / sample plant), while the two experimental inoculants (Signum and NS) and the control still did not develop nodulates. Examining the height of plant during the whole growing season, we experienced that among the inoculants, the stock remained 4 cm lower among the inoculants with the Blue Seed treatment, while for Signum and NS inoculants the difference were -2 cm compared to the control (57,8 cm). Examining the SPAD value of sleeve period [BBCH (69-75)], we experienced that the seed inoculation and the chlorophyll content of nodulate plants were not related, because the Blue Seed inoculant - treated plant population (which had nodulates) showed 2% lower SPAD compared to the control (43,6 SPAD). Based on the results of the number of pods, we established that, in terms of its tendency, on average 2 - 4 fewer pods were formed in the case of plants treated with different inoculants, while the development of the number of seeds was consistent accordance with the results obtained with the number of sleeves, but no significant difference could be detected and was perceptible from the numbers obtained, that the inoculants alone are not able to increase yield (Figure 2).

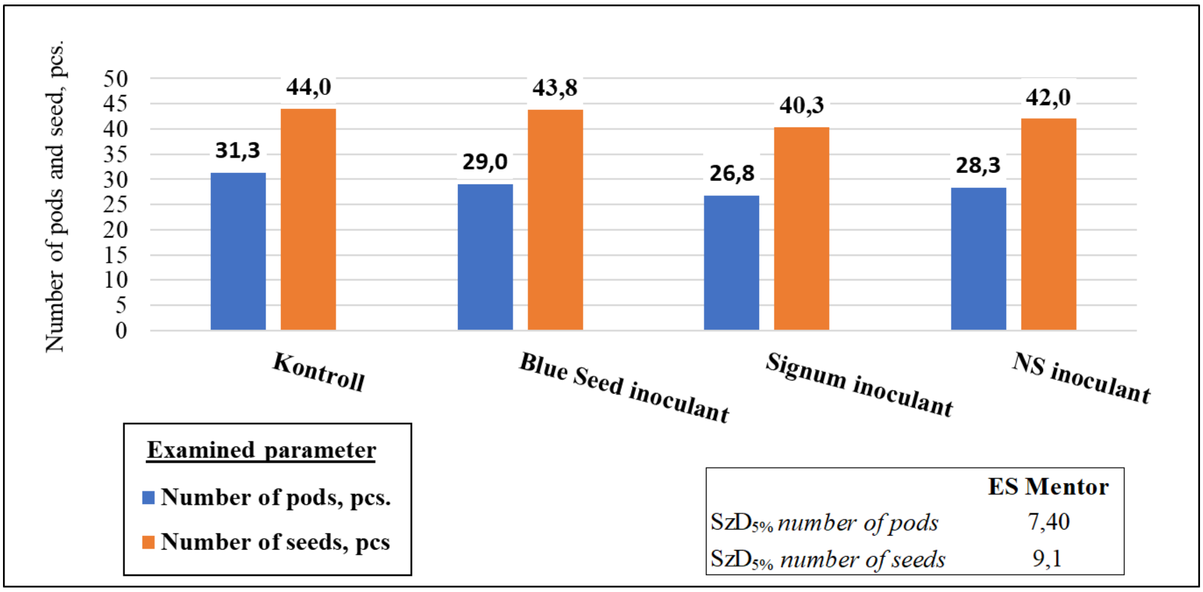

Figure 2. Results of the number of pods and seeds measured during ripening of ES Mentor soy variety treated with different inoculants, under small plot conditions (Hédervár, 2017)

Based on the yield averages, we established that the lowest yield (2900 kg ha^{-1}) was measured by Signum inoculant compared to the treatments and based on the statistical analysis, the average difference of 150 kg ha^{-1} was considered a significant difference (ES Mentor $SzD_{5\%}$ 89 kg ha^{-1}). Blue Seed proved to be the most effective inoculant, because it was only - 90 kg ha^{-1} lower than the control treatment (3050 kg ha^{-1}).

Analysing the oil and protein content, we established that the average protein content of the nodulate Blue Seed inoculant sample was the same as the control (30,9%), based on which we established that the amino acid content of soybeans did not increase due to nodulation, while Signum and NS inoculants showed 0,2-0,5% lower values.

Analysing the effect of the inoculants on the soybean variety with Pearson's correlation to SzD1%, we experienced that of the examined parameters, only the nodulation was affected and showed a very strong (0,742 **) relationship, while for parameters influencing yield we gotten low r-value, therefore we established there was no effect for plant height, number of nodes, number of pods and seeds, thus the result of the correlation test for yield, which was also a low r-value (0,254), is completely correct (Table 6).

Based on the results obtained for the SPAD- and oil-protein values, we also experienced that the inoculants cloud not influence these parameters, which may completely reshape the approach of current production practice (Table 6).

Table 6. Correlations of the effect of the inoculants used in the experiment determined by Pearson's correlation (Hédervár, 2017)

	Number of nodulate, pcs.	Plant height, cm	Number of nodes, pcs.	SPAD-value	Number of pods, pcs.	Number of seeds, pcs.	Averageyield, kg ha^{-1}	Protein content, %	Oil content, %
ES Mentor*inoculant	**0,742****	0,133	0,041	0,057	0,185	-0,213	0,254	-0,177	-0,131

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Test results for soybean seeds with different combinations of dressings and inoculants treatments

Our laboratory studies have shown that the already soil-specific bacterial strain Bradyrhizobium japonicum is strongly inhibited by the currently used Vitavax 2000. Therefore, in 2017, we performed not only on inoculants, but also on two dressings (Rancona 15 ME and Rancona i-MIX) which, based on our laboratory tests, support the bacterial strain *Bradyrhizobium japonicum* applied to the surface of soybean seeds. In the experiment, we looked for the answer to whether there is a more effective pairing of dressings and inoculants than the current combination (Vitavax 2000 and a different inoculant), which not only promotes the development of a uniform crop, but also supports the given variety during the growing period.

Examining the nodulation, we established that out of the 13 treatments during the flowering period [BBCH (63-67)], we took nodulate on the roots of the sample plants in 8 treatments, however, only two combinations were outstanding (Rancona 15 ME with Blue Seed inoculant: 4,00 pcs nodulates, Rancona 15 ME: 3,00 pcs nodulates) (Figure 3).

During the sleeve period [BBCH (69-75)], we continued to study the roots and found that only 7 of the 13 treatments contained nodulates at the roots of the sample plants, but only the Rancona 15 ME Blue Seed inoculant combination was 60% more effective compared to the treatments (Figure 4).

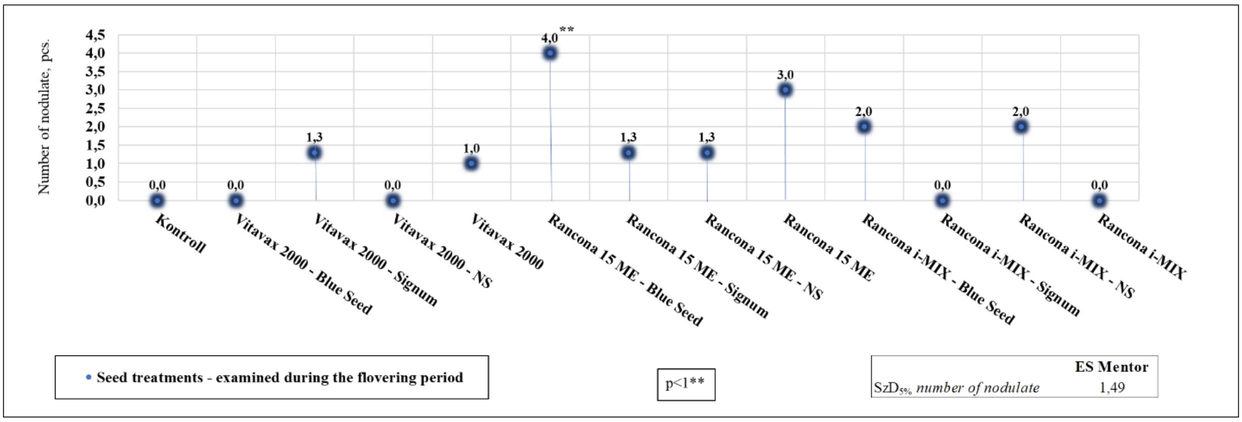

Figure 3. Results of nodulation by ES Mentor variety treated with different dressings and inoculants, examined from the agronomically important flowering period and under small plot conditions (Hédervár, 2017)

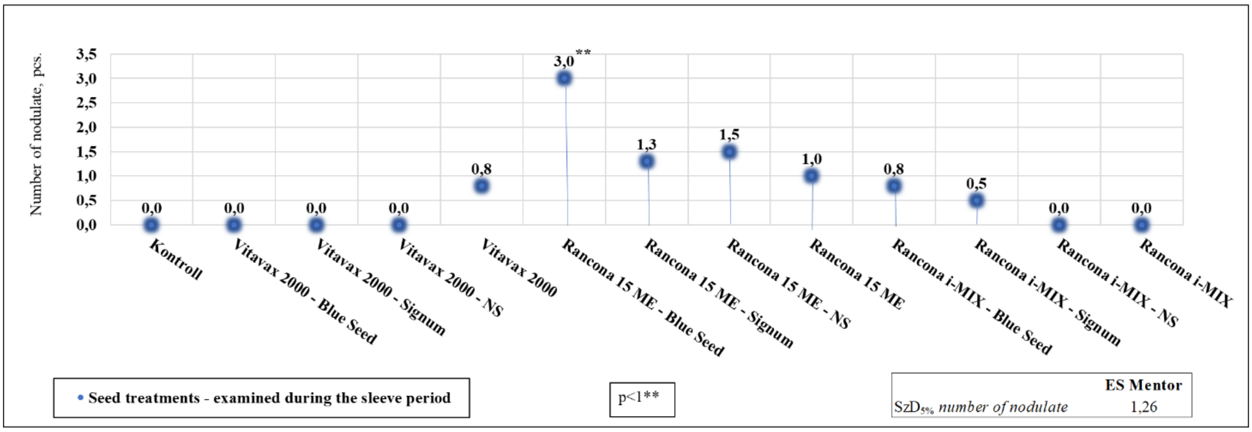

Figure 4. Results of nodulation by ES Mentor variety treated with different dressings and inoculants, examined from the agronomically important pods period and under small plot conditions (Hédervár, 2017)

Examining the plant height, we found that by the end of the growing season, only two combinations - Rancona 15 ME Signum and Rancona 15 ME NS inoculant - stood out by 5.5 cm from the treatments, which, based on statistical evaluation, also differed significantly from multiple treatments and control (Figure 5).

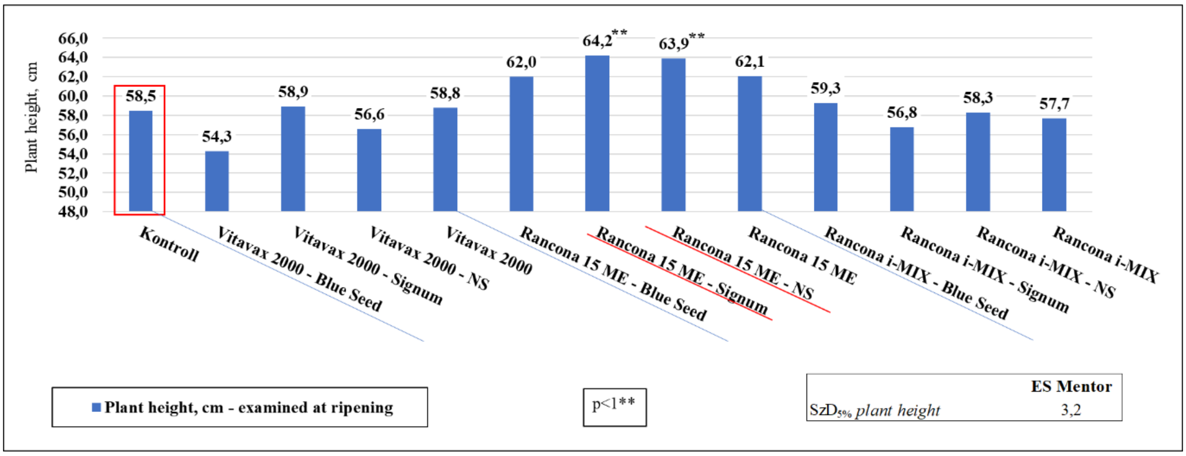

Figure 5. Plant height test result for ES Mentor soybean variety treated with different dressings and inoculants examined in the period of ripening from an agronomic point of view, under small plot conditions (Hédervár, 2017)

Measurements during the ripening period [BBCH (80-88)] showed that that in terms of the trend in number of pods, three treatments showed a 12% higher result (Rancona 15 ME Blue Seed inoculant: 33,3 pcs, Rancona i-MIX Blue Seed inoculant: 32,3 pcs, Rancona i-MIX NS inoculant: 32,5 pcs), as the control (28,5 pcs) and the treatments used in the experiment. When examining seed numbers, five treatments (Vitavax 2000: 102,9 pcs, Rancona 15 ME Blue Seed inoculant: 117,9 pcs, Rancona i-MIX Blue Seed inoculant: 114,7 pcs, Rancona i-MIX NS inoculant: 115,9 pcs-, Rancona i-MIX: 108,8 pcs) had on average 19% higher seed number than the control (93,9 pcs).

After harvest, we aggregated the yield averages, of which only three combinations stood out (Rancona 15 ME Blue Seed inoculant: 3120 kg ha^{-1}, Rancona i-MIX NS inoculant: 3080 kg ha^{-1}, with Rancona i-MIX Blue Seed inoculant: 3070 kg ha^{-1}) of the treatments, but the most effective were the Rancona i-MIX dressing and its combinations, which achieved an overall 2,7% higher yield compared to the Vitavax 2000 and Rancona 15 ME treatments (Figure 6).

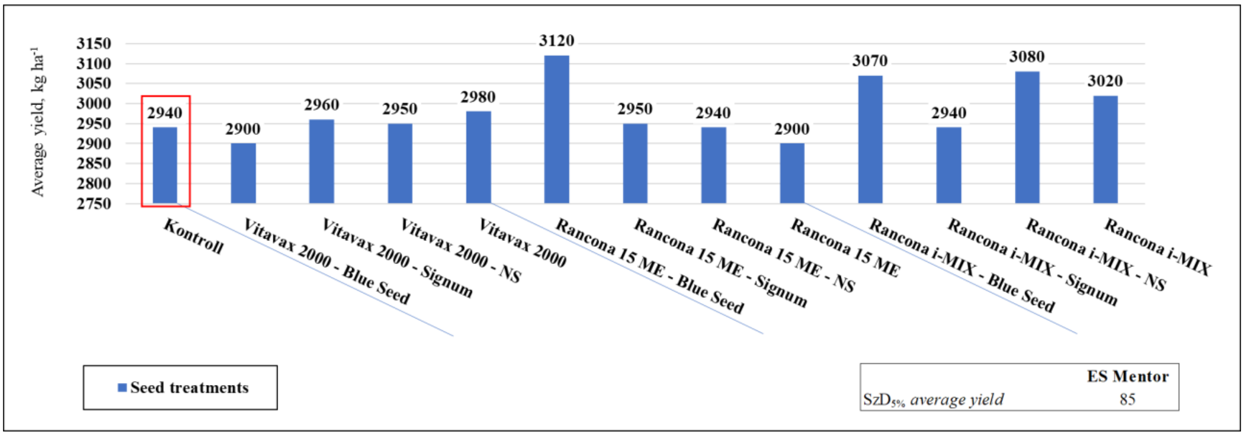

Figure 6. Yield averages of ES Mentor variety treated with different dressings and inoculants, under small plot conditions (Hédervár, 2017)

Analysing the oil- and protein indicators, we experienced that there is still no correlation between the highest yield and protein content, and we measured -0.7% lower protein values compared to untreated seed for 6 treatments (Vitavax 2000 and Blue Seed-, Vitavax 2000 and Signum-, Rancona 15 ME and NS-, Rancona i-MIX and Signum combination, and Rancona 15 ME- and Rancona i-MIX dressings) (Figure 7).

When examining the oil contents, we found that the Rancona 15 ME and NS inoculant was outstanding in terms of its tendency, which treatment differed from the results of the treatments by 0,3%, however, the difference cannot be considered significant (Figure 7).

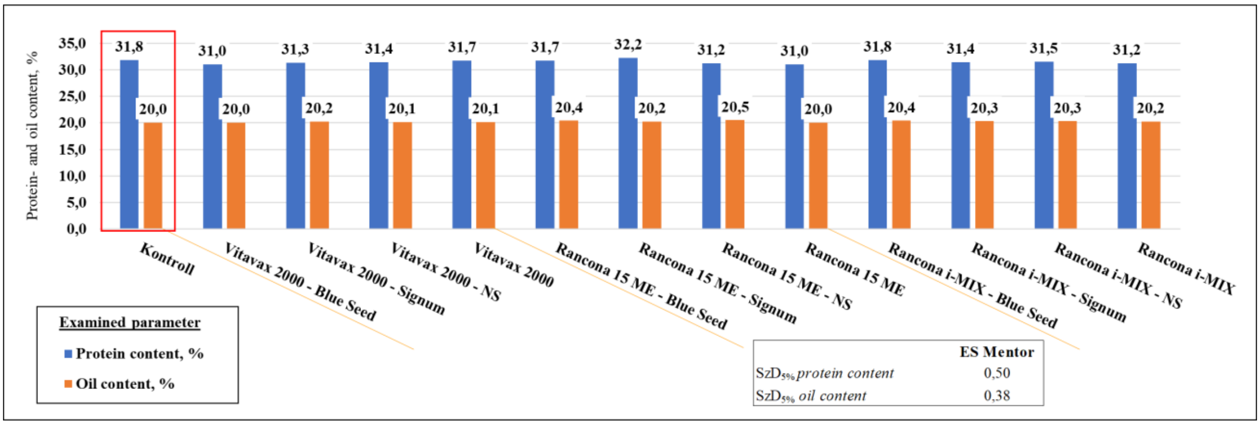

Figure 7. Oil- and protein content of ES Mentor variety, treated with different dressings and inoculants, under small plot conditions (Hédervár, 2017)

The combinations of dressings and inoculants used in the experiment often yielded significant differences in the statistical evaluation of the measured parameters, however, analysing the effect on soybean variety with Pearson's correlation at SzD1% and SzD5%, we obtained a strongly (0,519 **) relationship only in the case of nodulation, and we established that the nodulation on the roots of the plants formed as a result of treatment a, while we obtained low r - values for the other parameters, according to which the combinations of dressings and inoculants did not affect the growth, number of node, SPAD value, number of pod and seed, yield average, and oil – protein contents (Table 7). Examining the effect of dressings applied without inoculants on the plants, we found that they were able to influence the nodulation, to which a medium-strength (0,490 **) relationship was obtained. The results of the additional parameters were similar to those found for inoculants, according to which dressings did not affect plant height, number of nodes, SPAD value, number of pod and seed, yield average, and oil-protein content, because the analysis showed a low r value here as well (Table 7). Based on the results, we established that better yield averages were achieved in not as a result of treatments, but as a result of production.

Table 7. Correlations of the effect of dressings and inoculants used in the experiment determined by Pearson's correlation (Hédervár, 2017)

	Number of nodulate, pcs.	Plant height, cm	Number of nodes, pcs.	SPAD-value	Number of pods, pcs.	Number of seeds, pcs.	Averageyield, kg ha^{-1}	Protein content, %	Oil content, %
ES Mentor*dressing and inoculants combination	**0,519****	0,078	0,041	0,062	0,196	0,124	0,193	0,164	0,124
ES Mentor*dressing combination	**0,490****	0,170	0,041	0,141	0,067	0,153	0,024	0,123	0,196

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Test results of foliar fertilizer treatments

In 2018, under small plot conditions, we examined in four repetitions the a high-nitrogen foliar fertilizer with microelement supplementation (Plantal Top N, hereinafter referred to as “Treatment1”) and a new foliar fertilizer containing microorganisms (ACTIVSTART Arable Pulses with MC Mineral supplement, hereinafter referred to as “Treatment2”), with double application (before flowering, at the beginning of pods period).

Baseline values for the selected plots were recorded and the plants were treated in the pre-flowering period [BBCH (50-51)] with the following doses:

- *Treatment1*
  - 0,80 l ha^{-1} Plantal Top N + 40 l ha^{-1} water
- *Treatment2*
  - 0,40 l ha^{-1} ACTIVSTART Arable Pulses + 0.16 l ha^{-1} MC Mineral + 40 l ha^{-1}water

We were performed the studies in the second week after the treatment - in bloom [BBCH (64-66)] - based on which we established that the sample plants of the two different foliar fertilizers (*Treatment1* and *Treatment2*) tended to form 70-80% more nodulates than in the case of the control plants (2,5 nodulate), while compared to the two treatments, *Treatment2* gave the best results with an average of 51,5 nodulates (60,8 nodulates). In the study of plant heights, the plant stock of Treatment2 was 2,5 centimetres and on average 2 floors higher compared to Treatment1, while the control was only 1-2 centimetres lower for both treatments (63,6 cm and 10,7 nodes). At the SPAD values, the result of Treatment1 was on average 2% higher than the SPAD measured during the study period, which may be caused by a higher nitrogen dose of foliar fertilizer (Treatment2: 45,6 SPAD, Control: 44,7 SPAD).

The second treatment was performed when the first pods initiations appeared [BBCH (69-70)], then we measured the plants again at ripening period [BBCH (76-78)], based on the results of which we established that the number of nodulate in the case of *Treatment2* still increased by 19% compared to the two treatments (*Treatment1*: 25,3 nodulates, *Control*: 16,8 nodulates), while at plant height we found that the plants of the two treated areas developed much more dynamically than the control and the stock treated with mineral-supplemented foliar fertilizer was the highest with 14% (*Treatment1*: 75,0 cm, *Control*: 70,8 cm), while the number of node continued to follow the evolution of heights.

The initial contrast between the SPAD values decreased and a larger difference was observed only between *Treatment2* and control treatment with 5 SPAD value (*Control*: 14,8 SPAD), while analysing the results of the number of pods and seeds, we established that as a result of the treatments, *Treatment2* had on average 4 pods and 6 soybeans more than *Treatment1* (34,6 pods and 71,4 seeds), however the difference between *Treatment2* and *Control* was more spectacular, where the difference was already 6 pods and 8 soybeans per plant (*Control*: 32,6 pods and 69,2 seeds).

Analysing the average yields after harvest, we experienced that the yield of *Treatment1* and *Treatment2* was on average 210 kg ha^{-1} higher than the *Control* treatment (2870 kg ha^{-1}), despite the fact that at the time examined was not remarkably high of pod and seed numbers.

Examining the results of the protein and oil indicators, we established that *Treatment1* had 1,5% lower protein content, while *Treatment2* 2,1% had higher protein content than the *Control* treatment, based on which it became apparent that the soybean variety used in the experiment was more favoured by the foliar fertilizer combined with the mineral (*Treatment2*) than by the one with a high nitrogen content (*Treatment1*) (Figure 8). Examining the oil contents, we experienced that the higher protein content was still associated with a low value and the Control achieved an average of 0.5% higher oil content compared to the treatments (Figure 8).

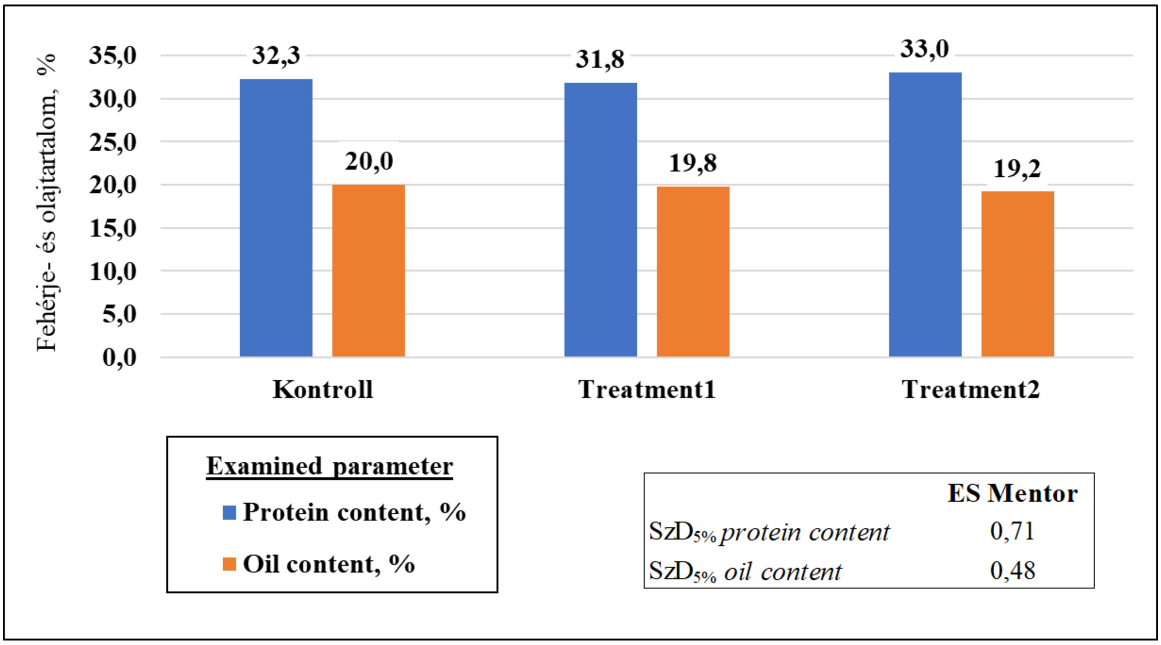

Figure 8. Results of protein- and oil content for the study of the effect of two different foliar fertilizer preparations used in the experiment (Hédervár, 2018)

During the studies we experienced significant differences in the treatment of several parameters, therefore we further analysed the obtained results on SzD1%, looking for the answer that the foliar fertilizer treatment really affected the soybean variety used in the experiment, or only was observed the effect of cultivation. Based on the results obtained by Pearson's correlation, we established that the foliar fertilizer treatment did have with medium strength affected on nodulation (0,485 **), plant growth (0,445 **), number of nodes (0,330 **), number of pods (0,343 **) - and the number of seeds (0,349 **), while in the case of SPAD and yield average it already showed a strongly relationship (0,602 **; 0,627 **) as a result of the treatments. In the case of oil and protein content, we could clearly see that the higher protein content was not due to treatment, because the analysis showed a low r - value, as for oil content (Table 8), thereby established that well-chosen foliar fertilizer for cultivation has been shown to improve yields, but does not provide above-average protein and oil content.

Table 8. Correlations of the effect of foliar fertilizer treatment applied in the experiment determined by Pearson's correlation (Hédervár, 2018)

	Number of nodule, pcs.	Plant height, cm	Number of node, pcs.	SPAD-value	Number of pods, pcs.	Number of seeds, pcs.	Average yield, kg ha^{-1}	Protein content, %	Oil content, %
ES Mentor*florial treatment	0,485**	0,445**	0,330**	0,602**	0,343**	0,349**	0,627**	0,228	0,176

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Presentation of the results of irrigation applied in soybean production in the region of Western Hungary with two different doses (30- and 60 mm)

The experiments were performed in all three years (2016, 2017, 2018) on 0.5 ha per treatment, for which a 0.5 ha non-irrigated control area was designated. Studies in 2016 were started before irrigation (at the beginning of flowering) and in the plant population — we measured the plant height, number of nodes, and SPAD-value — so that we can see the effect of irrigation.

Based on the results, it was established that in any of the areas have not nodulate on roots, however, the height of the sample plants treated with 60 mm of irrigation water stood out among the irrigated areas, where the plants were 14% higher than the 30 mm of irrigated water (68,6 cm) and non-irrigated plants (62,6 cm).

The number of nodes changed according to the height, but the difference can be said to be small, because the stock of the area treated with 60 mm of irrigation water was only 1 level more (plants 30 mm of irrigation water treatment: 11,4 pcs-, Control: 10,7 pcs of node). Examining the SPAD - values, we established that there was a significant difference between irrigated and non-irrigated stands and apparently the 60 mm irrigation water had the best effect (5,1 SPAD) on the chlorophyll content of the soybean variety in the experiment (plants 30 mm irrigation water: 42,3 SPAD, Control: 39,6 SPAD).

The last measurement was made during the ripening period [BBCH (80-89)] and we were established that the irrigation water was well utilized because the irrigated stands were 6% higher, but did not have significantly more nodes (0,8 nodes) in the compared to non-irrigated area.

When examining the number of pods, we established that in the case of 60 mm irrigation water we measured on average 5 pods more, which was followed by the number of seeds, so 12% more soybeans were formed per plant in the examined period, which was considered a significant difference based on statistical evaluation (Figure 9).

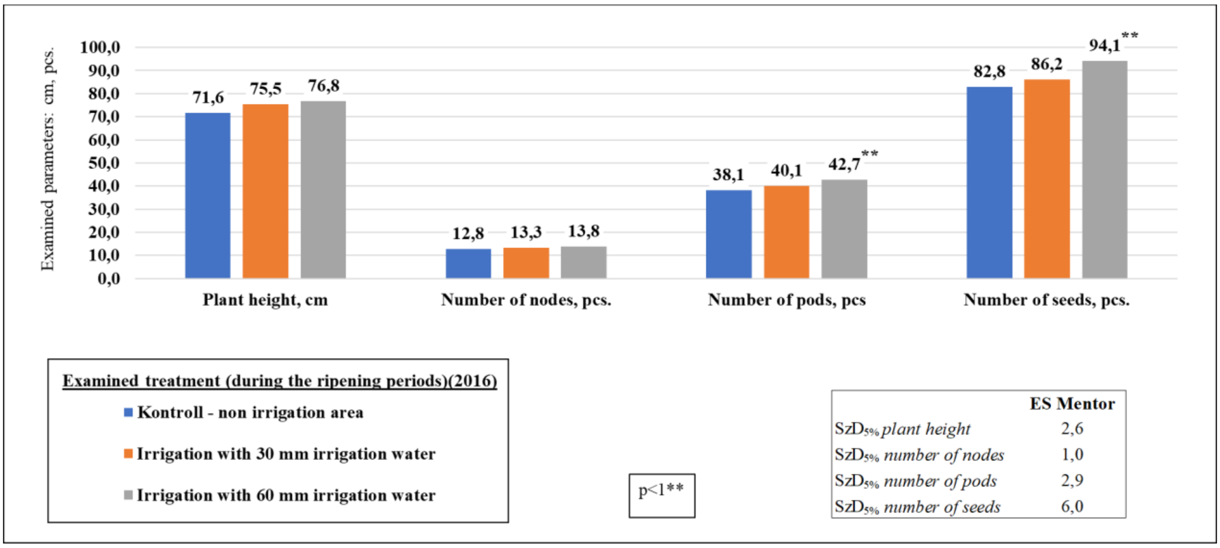

Figure 9. Results of surveys carried out during ripening, under semi-industrial conditions (Mosonudvar, 2016)

After harvest, the obtained yield averages and oil-protein content were evaluated. Based on the results, we established that as a result of irrigation, yields improved by 13% compared to the non-irrigated area (3660 kg ha^{-1}), which was also supported by the statistical analyses, because we obtained a significant difference only in the irrigated areas ($SZD_{5\%}$ 243 kg ha^{-1}), while in the case of oil abd protein contents, a similar positive change were observed only in the oil content, where the oil content of soybeans increased on average by 1,1% compared to the control (20,3%) as a result of precipitation supplementation (Table 9).

Table 9. Yield averages, protein and oil content of the ES Mentor soybean variety used in the experiment, under the influence of 30- and 60 mm irrigation water applied during flowering, under semi-industrial conditions (Mosonudvar, 2016)

Year 2016.	Irrigation with 30 mm irrigation water	Irrigation with 60 mm irrigation water	Control - non-irrigated area
Avarage yield, kg ha^{-1}	3910	4220	3660
Protein content, %	31,8	32,1	31,9
Oil content, %	20,9	21,4	20,3

For the studies performed in 2017, we proceeded in the same way as in 2016. Irrigation was again performed during the flowering period, and then the plants parameters were measured during the sleeve period [BBCH (72-74)].

Based on the results, we found that at 60 mm irrigation water the plant stock was 11% higher compared to the two treatments (30 mm irrigation water plant stock: 65,7 cm, Control: 60,7 cm), while at the SPAD - value was 3,9 SPAD higher than the other treatments (30 mm irrigation water volume: 43,6 SPAD, Control: 40,3 SPAD). Based on the results of the measurements performed during the ripening period [BBCH (80-89)], we established that the plant stands in the irrigated areas differed by 4,9 cm in height, while in the number of nodes only the sample plants given 60 mm irrigation water stood out on average 1,3 levels, but the statistical evaluation did not show a significant difference. Examining the number of pods, we experienced that on the irrigated plant stocks had an average of 37 pods more, while in the case of 60 mm of irrigation water we measured 11% more than the plant stock treated with 30 mm of irrigation water. In terms of number seeds, the plant stock how received 60 mm of irrigation water was more prominent in its tendency, which differed on average by 12 soybeans per plant compared to the two treatments (Figure 10).

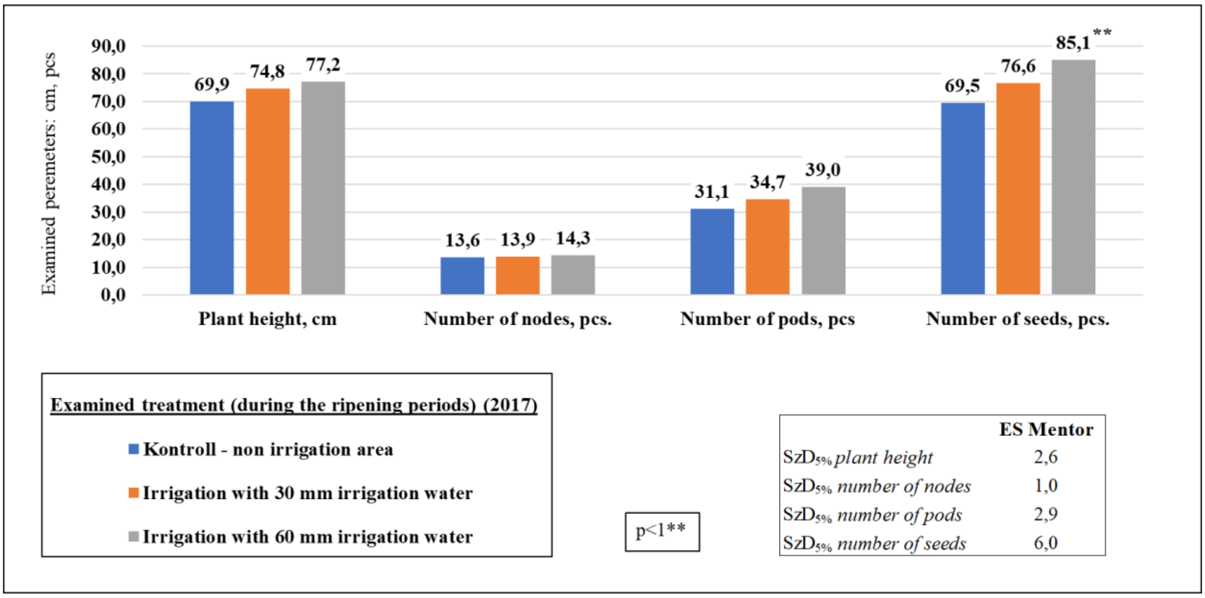

Figure 10. Results of surveys during ripening, under semi-industrial conditions (Mosonudvar, 2017)

After the harvest, we established that the irrigated areas achieved higher yields in 2017 compared to the non-irrigated area, however, only in the case of 60 mm irrigation water we measured a 9% higher yield average compared to the two treatments, while compared to the 30 mm irrigation water treated plant stock difference was 220 kg ha^{-1} soybean (Table 10).

The results of oil and protein content were similar to 2016, the protein content was not affected by irrigation and we did not find a significant difference ($SZD_{5\%}$ 0,27%) between the treated and control areas, while the oil content increased again by 1,1% indicators of irrigated areas compared to Control (Table 10).

Table 10. Yield averages, protein and oil content of the ES Mentor soybean variety used in the experiment, under the influence of 30- and 60 mm irrigation water applied during flowering, under semi-industrial conditions (Mosonudvar, 2017)

Year 2017.	Irrigation with 30 mm irrigation water	Irrigation with 60 mm irrigation water	Control - non-irrigated area
Avarage yield, kg ha^{-1}	3970	4190	3640
Protein content, %	31,8	31,9	31,9
Oil content, %	21,7	21,9	20,8

We continued the experiment in 2018, and we continuously monitored the vegetation during the agronomically highlighted phenophases. The measurements were performed in the same periods as in the previous two years. The data recording was performed after the irrigation - during the sleeve period [BBCH (72-74)] - and based on the results we concluded that, as in previous years, the plant height and SPAD - value of irrigated areas were more outstanding by 5%, and the latter 8,3 SPAD, while the number of nodes changed in proportion to the plant height, however, it did not show a significant difference compared to the non-irrigated area (Table 11).

Table 11. Results of measurements after irrigation, in the period of sleeve, under semi-operational conditions (Mosonudvar, 2018)

Year 2018 (II. measurement)	Irrigation with 30 mm irrigation water	Irrigation with 60 mm irrigation water	Control - non-irrigated area
Plant height, cm	60,5	63,9	57,3
Number of nodes, pcs	10,9	12,0	10,3
SPAD-value, SPAD	45,6	47,7	38,4

The last measurements were taken at the time of ripening [BBCH (80-89)], based on the results of which we established that during the whole growing period, including the ripening period, the irrigated plant samples showed higher values at plant height, but the 60 mm irrigated plant stock was spectacularly (6 %) higher, while the number of nodes varied in proportion to the plant height, so this was 1,4 more levels compared to the two treatments. The final result of the number of pods showed that 6% more pods were formed in the 60 mm treatment compared to the result of the plant stock treated with 30 mm irrigation water, while compared to the non-irrigated we measured on average 4,4 pods more in the 30 mm and 60 mm irrigation water areas. The development of the number of seeds was adjusted to the number of pods, therefore the most prominent in terms of its tendency was the treatment with 60 mm irrigation water 11% more soybeans per plant, while we experienced an average difference of 6% in the number of seeds between the two irrigations treatments, which also showed a significant difference in the statistical analyses (Figure 11).

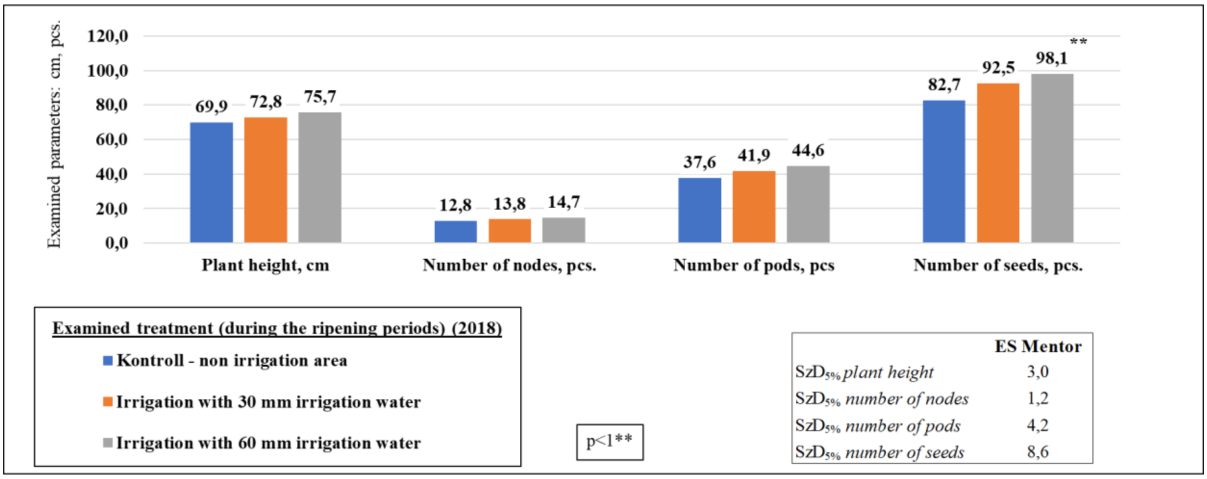

Figure 11. Results of surveys during ripening, under semi-industrial conditions (Mosonudvar, 2018)

We evaluated after the harvest the yield averages, protein and oil content of irrigated and non-irrigated areas. The higher yield was again given by the irrigated areas, of which the plant stock treated with 60 mm irrigation water 470 kg ha^{-1} achieved a better average yield compared to the area treated with 30 mm irrigation water and the non-irrigated area, but based on the protein content of the average samples we did not find a significant difference between the treatments ($SzD_{5\%}$ 0,24%), while for oil contents, the value of soybeans treated with 60 mm of irrigation water increased by 1,4% compared to the non-irrigated area (Table 12).

Table 12. Yield averages, protein and oil content of the ES Mentor soybean variety used in the experiment, under the influence of 30- and 60 mm irrigation water applied during flowering, under semi-industrial conditions (Mosonudvar, 2017)

Year 2018.	Irrigation with 30 mm irrigation water	Irrigation with 60 mm irrigation water	Control - non-irrigated area
Avarage yield, kg ha^{-1}	3780	4090	3460
Protein content, %	31,9	32,1	32,0
Oil content, %	21,4	21,8	20,4

Based on the results of the three years, we sought the answer to the extent to which irrigation affected plant height, SPAD value, number of pods and seeds, yield average, and oil content, which showed significant differences in the processing of the results.

The analysis was performed by Pearson's correlation on $SZD_{1\%}$, based on which we established that irrigation had a moderate effect on plant growth, pod and seed numbers, and consequently on yield and oil content, but had no effect on number of nodes and the protein content. It had the greatest influence on the SPAD values, which showed a strong (0,566 **) relationship in the analysis, but the higher chlorophyll content was not manifested in the protein content as expected (Table 13).

Table 13. Correlations of the effect of irrigation applied in the experiment determined by Pearson's correlation (Mosonudvar, 2016 - 2018)

	Plant height, cm	Number of node, pcs.	SPAD-value	Number of pods, pcs.	Number of seeds, pcs.	Average yield, kg ha^{-1}	Protein content, %	Oil content, %
ES Mentor * Irrigation	**0,506****	-0,226	**0,566****	**0,308****	**0,351****	**0,485****	0,160	**0,501****

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Site-specific effects on soybean average yield, protein- and oil content, analysed by Pearson's correlation (Mosonudvar and Bóly, 2016-2018)

Using the three - year data set, we sought to answer the question of the relationship between two or more factors - soil inoculation, irrigation, temperature, precipitation - yield average, protein- and oil content. For the evaluation, we used the test results and measurements of two experimental areas (Mosonudvar and Bóly) for three (2016-2018) years.

In Mosonudvar and Bóly, we experienced during the processing of the results, that the irrigation significantly affected the yield averages and oil content of the soybean varieties used in the experiment with the treated soil inoculant products, however, it did not affect protein synthesis, while inoculation without irrigation had no positive effect. Based on the results of Pearson's correlation analysis, we confirmed that irrigation did indeed influence the yield averages and oil contents with a medium-strength (0,416 **; 0,310 **) correlation in Mosonudvar and showed a strong (0,645 **; 0,558 **) relationship at Bóly (Tables 14 and 16), while the results of soil inoculation studies showed that it did not affect the parameters because low r values were obtained in all cases.

The two experimental areas differ greatly in terms of weather factors, therefore, using the correlation, we further examined that the monthly precipitation and average temperature can influence soybean varieties grown in the areas. Based on the results, we experienced that the monthly precipitation of Mosonudvar, located in the slightly rainier region of Western Hungary, strongly influences the annual yield averages, while the oil content can be visible in a medium-strong and then in a strong relationship in May-July, what will determine the oil content of the variety, however, protein synthesis was not affected by the amount of precipitate (Table 14). Based on the results measured in Bóly in the Southern Transdanubia region, we experienced that precipitation has an even more pronounced effect on the average yield and oil content. Based on the analysis, the total growth period is influenced by the amount of monthly precipitation from April to August for both examined factors, showing a strong relationship, while the protein content was still not affected by the amount of precipitation (Table 16). Examining the effect of monthly average temperatures on yield, oil and protein content, we experienced that has a decisive and strong influence on yield in both locations from the time of sowing, and from May it is moderate, but influences the development of oil content until August, while at the protein content we obtained consistently low r - values, according to which temperature does not affect this factor either (Tables 15 and 17).

Table 14. Correlations of the effect of soil inoculation, irrigation and precipitation determined by Pearson's correlation (Mosonudvar, 2016 - 2018)

Mosonudvar	Soil inoculation	Irrigation	April precipitation	May precipitation	June precipitation	July precipitation	August precipitation	September precipitation
Avarage yield, kg ha^{-1}	0,203	0,416**	0,636**	0,601**	0,635**	0,687**	0,608**	0,040
Protein content, %	0,135	-0,069	0,143	-0,198	0,176	0,141	-0,119	0,093
Oil content, %	0,072	0,310**	0,250*	-0,532**	-0,611**	0,565**	0,447**	-0,110

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Table 15. Correlations of the effect of the monthly average temperature determined by Pearson's correlation (Mosonudvar, 2016 - 2018)

Mosonudvar	April temperature	May temperature	June temperature	July temperature	August temperature	September temperature
Avarage yield, kg ha^{-1}	0,464**	-0,303**	-0,700**	0,686**	0,757**	0,105
Protein content, %	0,020	-0,124	0,112	0,177	-0,195	0,051
Oil content, %	0,169	0,327**	-0,405**	0,500**	0,345**	0,070

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Table 16. Correlations of the effect of soil inoculation, irrigation and precipitation determined by Pearson's correlation (Bóly, 2016 – 2018)

Bóly	Soil inoculation	Irrigation	April precipitation	May precipitation	June precipitation	July precipitation	August precipitation	September precipitation
Avarage yield, kg ha^{-1}	0,173	0,645**	0,552**	0,619**	0,636**	0,714**	0,593**	0,099
Protein content, %	0,128	0,091	0,221	0,171	0,160	0,126	0,118	0,090
Oil content, %	0,142	0,558**	-0,513**	0,615**	-0,699**	0,608**	-0,508**	0,098

** The correlation is significant the 1% level; * The correlation is significant the 5% level

Table 17. Correlations of the effect of the monthly average temperature determined by Pearson's correlation (Bóly, 2016 - 2018)

Bóly	April temperature	May temperature	June temperature	July temperature	August temperature	September temperature
Avarage yield, kg ha^{-1}	0,565**	0,498**	-0,633**	0,734**	-0,782**	0,145
Protein content, %	0,113	-0,121	0,141	0,130	-0,147	0,074
Oil content, %	0,214	0,420**	0,550**	-0,466**	-0,413**	-0,083

** The correlation is significant the 1% level; * The correlation is significant the 5% level

4. NEW SCIENTIFIC RESULTS OF THE DISSERTATION

We examined some elements of the Hungarian general soybean varieties technology and their development possibilities, such as: the use of different row spacing, dressings and inoculants, the influence of two foliar fertilizers applied at three different varieties (ES Mentor, Sy Eliot - very early-, Steara-middle ripening group), and certain key agrotechnical elements: the effect of soil inoculation and irrigation, in parallel in two sample areas (Mosonudvar and Bóly) with two different varieties (ES Mentor - very early- and Steara middle ripening group), which have not been evaluated in Hungarian research and they have not been published in the Hungarian literature.

Our new scientific results influencing the yield, protein- and oil content of the field-specific treatments applied for the soybean production in domestic are the following:

1. Based on the results of the three years, we found that the effect of the arable land treated with the soil inoculation product on the yield resulted in an 8% lower yield in the case of cultivation without irrigation, while the application of 30 mm irrigation water increased the yield by 10%. therefore, in order to increase the effectiveness of the treatment, the microclimate of the site, the amount of rainfall during the vegetation and the appropriate irrigation of the treated stock should be taken into account in order to increase the effectiveness of the treatment.

2. The inoculated seeds did not affect the yield averages, and the seed without inoculant yielded a higher yield of 120 kg ha^{-1} in our experiment compared to the treatments, so we found that the use of inoculants therefore, these complex relationships require further investigation. Our further result is that the more modern dressings containing the active ingredient ipconazole are much more compatible with the bacterial strain Bradyrhizobium japonicum in the soy vaccine, so a better cultivation technology can be developed in the near future using them. As a result of the application of the appropriate technology, 60% more nodulates were formed at the roots of the plants at the time of flowering compared to the control, and yields increased by 140-180 kg ha^{-1} compared to the control (2940 kg ha^{-1}).

3. The effectiveness of foliar fertilizer treatment in cultivation depends not only on its composition, but also on the time of and the frequency of application. Based on the results of our studies, ACTIVSTART + MC Mineral foliar fertilizer improved the yield of the soybean variety used in the experiment and resulted in an average yield increase of 210 kg ha^{-1} compared to the untreated stand. The formulations had a negligible effect on the protein content compared to the control, which showed that foliar fertilizer alone could not increase the content in all cases, but could effectively increase the average yield in some cultivars.

4. Although soybean irrigation is not possible in all areas at the national level, where this technological element can be applied, the application of 30-60 mm of irrigation water in two or more installments (during the period of germination, flowering, podging) can be considered effective. Our results confirmed that the irrigation started at the beginning of flowering is already productive, as in the case of 30 mm of irrigation water the yield averages increased on average by 10% compared to the control, while in the case of 60 mm the average yields increased by 16%.

5. PRACTICAL RESULTS

1. In the case of sowing agents for use in soybean cultivation, it is always necessary to adjust the composition of the soil inoculant to the production area and it is recommended to apply the multi-component strain, not just *Bradyrhizobium japonicum*, because the nitrogen requirement of soy is not only that. Based on the results of the one-component formulation used in our experiment, which contained only the bacterial strain Bradyrhizobium japonicum, we concluded that no symbiosis developed under non-irrigated or irrigated conditions that would have supported nodulation formation, therefore further studies are needed to promote efficient nodulation formation. During cultivation, only the treatments supplemented with irrigation as a technological element showed positive differences compared to the non-irrigated stands 345 kg ha-1 yield increase. These results show that it is advisable to combine it with irrigation in order to be effective of the soil inoculant treatments.

2. Yield growth based on inoculated seeds and the effects of nodulation formation is not a realistic expectation in Hungarian cultivation practice. The inoculum alone does not affect the fertility and yield of soybeans, and it has been found that nodulates appearing after inoculated seed are not always able to affect the protein content. Based on our research results, we found that 1-2 nodulates formed on the roots of the examined plants as a result of the Hungarian Blue Seed inoculant, however, the plants with nodulates remained on average 4 centimeters and 2 pods lower compared to the control stock. We had a further negative experience that the average yield was 90 kg ha^{-1} less than the control, which proves that the germinated herd does not always result in an increase in yield.

3. From 2020, dressed soybean seeds contain mostly ipconazole, which inhibits the growth of the bacterial strain *Bradyrhizobium japonicum* less than after sowing, which resulted in a 60% increase in the number of nodulates in the experiments - and an average of 6 centimeters of treated plants compared to control stock. The plants treated with the dressings used in the experiment also achieved good results in terms of number of pods and seeds (12% more pods and 22 soybeans per plant), and we found that the appropriate germination protection could increase the yield by 155 kg ha^{-1} to the untreated plant compared to.

4. The row spacing used in cultivation and the seed norms associated with them also vary in Hungary and by farmer and production area, as well as by variety. Based on the results of the very early soybean cultivars examined in our experiment, we found that the plants were 5 cm taller at 24 cm row spacing, formed 10% more pods, and the number of soybeans per plant increased by 8% compared to 75 cm row spacing. Yields were similar, with a higher yield of 200 kg ha-1 at the 24 cm row spacing compared to the 75 cm row spacing. In the case of the medium-ripening soybean variety, we found that it performed well not only in the 75 cm but also in the 24 cm row spacing, which was 8 centimeters higher in plants, 17% more pods and 10% more seeds. me. Yield averages also stood out compared to the 48 cm row spacing, averaging 240 kg ha-1, indicating that 24 cm and 75 cm of the row spacing chosen for the variety used in the experiment were actually able to influence cultivation with the lowest seed rate and have a yield-increasing effect.

5. In most cases, the composition of the foliar fertilizer compositions used in soybean cultivation determines the time of correct application. Among the formulations used in our experiment, plants were 8 centimeters taller, 10% better in pods and 7% better in seeds with the ACTIVSTART + MC Mineral foliar fertilizer treated compared to Plantal Top N. The increase in yield was also achieved as a result of the treatments, which higher was 80 kg ha^{-1} more than the yield of the herd treated with Plantal Top N foliar fertilizer, however, this surplus does not provide the possibility to expand the practical technology. Based on the results, it can be stated that the applied foliar fertilizers are actually able to have a positive effect on the parameters influencing the yield of soybeans, but a significant increase in yield cannot be achieved with these technological elements alone.

6. Actual yield growth was achieved with two different doses of watering during soybean flowering over the three years. The most productive were the 60 mm irrigated plants, where we measured 3 cm higher plants on average, 6% higher number of pods and seeds compared to the 30 mm irrigated area, while we found even greater differences compared to the non-irrigated area (6 cm difference in plant height, 16% difference between pod and seed numbers). Based on our experiments, the treatment with 30 mm of irrigation water proved to be effective, because compared to the non-irrigated area, the plant population was 3 centimeters higher, with an average of 4 pods and 10 soybeans per plant. At 60 mm irrigation, 630 kg ha-1 and at 30 mm irrigation, 320 kg ha^{-1} soybean yield was higher compared to the non-irrigated area. Thanks to the Hungarian support policy, irrigation is being developed in more and more places, so it is worth incorporating this additional agrotechnical element into the soybean production technology to offset the increasingly fluctuating rainfall and heat stress, making it more efficient in meeting domestic protein needs.

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List of publications related to the dissertation

Hungarian scientific articles in Hungarian journals (1)

1. **Nagy, N. E.**, Bojté, C., Tatárvári, K.: Eltérő szójatermesztési technológiák összehasonlító elemzése az igen korai éréscsoportban.
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