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THE EFFECT OF DIFFERENT FERTILIZER DOSES ON THE YIELD OF SOYBEAN VARIETIES CULTIVATED IN THE CENTRAL HUNGARIAN REGION ON THE BASIS OF THE RESULTS OF THE CULTIVATION TECHNOLOGIES IMPLEMENTED IN THE VEKOP-2.1.1-15-2016-00177 TENDER

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Abstract
„Within the framework of the tender, we sought the answer to the question of what production technology can be used to successfully grow soybeans in the Central Hungarian region. This region has the lowest national soybean production area (637 ha), which is particularly difficult to increase further due to high production costs and extreme weather conditions. At the same time, the demand of the domestic processing industry for soybeans is constantly increasing, which is mainly covered by foreign imports. In this article we present three varieties of the Hungarian feed company (Galldorf Zrt.) with very high protein content and drought tolerance, which are marketed and grown in this special production area. The goal is to have a yield of more than 2 t ha^{-1} with a ProFat content more than 50%, which is suitable for full-fat soybeans for dynamic pork upbringing and the production of high-quality pork.”

1. Introduction

In Hungary, the area under the soybeans doubled in 2015 as a result of a new support program [1]. This set a new goal in domestic production, according to which the continuous support is expected to increase the production of soybeans, as a result of which the number of imported soybeans can be reduced, the origin of which is increasingly questionable. The domestic market also does not support the production and processing of GM soybean products. However, this is becoming increasingly difficult to do because the developing countries are growing with GM soybeans because they require fewer chemicals to produce them and have higher yield potential [2, 3].
By dividing the nationwide soybean production area into a regional level, it can be seen that the Central Hungary region has the smallest sown area in each examined year (2015-2018) (Table 1) [4].

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Therefore, within the framework of the Competitive Central Hungary Operational Program tender (VEKOP-2.1.1-15-2016-00177), we undertook to develop a soybean production technology, which do mainly used for the short-grown season (85-130 days), the super- early, very early, early and early- middle ripening varieties suitable for the production.

The production cost of the technology is optimal and in all conditions, it can produce the desired yield of 2000,00 kg ha^{-1} or more, as a result of which the size of the sown area in the Central Hungary could be start to increase.

Table 1. Regional distribution of soybean sowing areas in Hungary (2015-2018)

Sowing area (ha^{-1})				
Region	**2015**	**2016**	**2017**	**2018**
Central Hungary	***918***	***664***	***955***	***759***
Central Transdanubia	4 722	3 478	3 513	2 459
Western Hungary	13 451	14 223	21 072	17 815
Southern Transdanubia	26 730	21 474	25 073	23 108
Northern Hungary	5 794	4 487	5 962	3 932
Northern Great Plains	3 899	3 597	3 668	2 943
Southern-Great Plains	16 502	13 106	15 424	11 102

In addition to the high average yield, the technology can ensure good quality and outstanding protein and favourable oil content, which is an increasing expectation from industrial processors.
Nowadays, this can be a problem because there are so many sales and breeding houses on the market, so many kinds of recommendations are received from farmers, but they can never be fully and unchanged adapted to any domestic area. The farmer has to know the field area capability which would to soybeans production, but also how much time is available, has if the optimal sowing time is delayed. The wide range can be further reduced if the producer knows what the needs of the particular variety are, such as rainfall, heat demand and nutrient supply and corresponds to the selected variety or not [5]. In Hungary, the most common row spacing is the 12-24-36-45 cm, but many farmers apply the so-called wide (50-60-75 cm) row spacing too [6]. However, in order to choose the right row spacing, it is necessary to know the habitus of the variety and its reactions to weather conditions. There is a variety that, under poor conditions, remains well below the height given in the variety description, which is not at all favourable to the producer or the expected yield [7].

2. Material and Method

Introducing varieties

In the experiments we used soybean varieties that tolerate the sowing distance of the grain with a grain seed drill (12-24-36-48 cm) and they have to ripen in all weather conditions in time (September-October), they can be harvested easily with minimal losses. **ES Mentor** and **ES Advisor** belong to the very early and early, while **ES Mediator** belongs to the middle-maturing group [8].
The maturation time for ***ES Mentor*** is up to 129 days, while for ***ES Advisor*** is 132 days and for ***ES Mediator*** is 135 days. Their nutrient requirements are characterized by the fact that they are able to achieve a crude protein content of 30% or more at a low nitrogen dose (~40-60 kg ha^{-1} of nitrogen active ingredient), which is especially important for the Hungarian feed industry.
In addition, well tolerated, low rainfall periods and extreme fluctuations (heat days, permanent cooling, etc). They have excellent tolerance and resistance to the disease (*Sclerotinia sclerotiorum*, *Fusarium spp*). Their weed suppressor capability is weak during the initial development period, so after sowing, before germination, it is necessary to treat the herd with pre-emergent weed control. ***ES Mentor*** is characterized by chemical sensitivity, therefore post-emergence treatment of the herd

is not recommended. ***ES Advisor*** and ***ES Mediator*** tolerate weed control in the 2-8 leaf stage well, but mechanical weeding control is then recommended because excessive chemical use greatly increases production costs, which cannot be incorporated into the purchase price of the final product.

Introduction of production areas

Based on the Hungarian field category classifications for the cultivation of soybeans, it can be stated that the I.- (Chernozem soils) and II. field categories (Brown Forest soils) are the most suitable because their structure is crumbly, the pH of the soil is weakly acidic, neutral or weakly alkaline, and moderately or well supplied with nutrients. Pest County mainly these two categories are mixed, but a small percentage occur meadow- and framework soils also are partially or totally unsuitable for soybean cultivation, because the air- organic material- the ratio of water is not appropriate for the culture as well as nutrient supply is poor [9].
The characteristics of the selected areas in 2018-2019 were as follows:

- **Újhartyán:**
  - II. field category of production category,
  - Physical types of soil: loam,
  - Weakly alkaline pH (pH: 7.5),
  - Humus content: 2.4%.

- **Vácszentlászló:**
  - II. field category of production category,
  - Physical soil type: clay loam,
  - Slightly acidic pH (pH: 5.5),
  - Humus content: 1.6%.

- **Cegléd**
  - II. field categry of production category,
  - Physical types of soil: loam,
  - Acidic pH (pH: 5.4),
  - Humus content: 1.8%.

Their nutrient supply is characterized by good or medium nitrogen; medium or low potassium and phosphorus supply, so nutrient doses changed as a function of this in 2018-2019.

The line spacing selection

The well-used (12-24 cm) grain spacing is well tolerated by most very early- and early ripening varieties in Hungary and achieves outstanding results in many demonstration areas. Fewer varieties from the middle- and late-maturing groups are suitable for this purpose, but the yields of the shorter-growing cultivars (maximum 135 days) are only slightly lower than those of their cultivars grown at wider (50-75 cm) row spacing. Aware of this, the varieties included in the project were sown to 24 cm in both years (2018-2019).

Nutrient supply

In addition to the choice of row spacing, the need for the variety of nutrients is very outstanding because it determines the final product (soybean) the protein and oil content. If seed is produced, it is worth applying the minimum nitrogen, potassium and phosphorus active ingredients, because the goal is to produce a higher quality hereditary material with optimal and non-record yields, in contrast to industrial soybean production, where not only quantity but quality is also a priority. The aim of the tender was a high-protein feed material with an outstanding yield, so two areas supplied with different doses of nitrogen fertilizer, until the third area not received fertilizer, so it was the control in 2018 (Table 2). Yields well reflect the importance of nutrient replenishment described in the literature [10, 11, 12, 13, 14] and the differences observed in the practice. The nutrient supply capacity of soils is very variable, different from each other in space and time, therefore in order to achieve adequate yields (> 2000,00 kg ha^{-1}) and high protein content, justifiable a minimum of 50,00 kg ha^{-1} of nitrogen active ingredient. Therefore, in 2019, we repeated the cultivation and fertilizer is applied by all three of arable land, to make visible the importance of nitrogen fertilizer. In 2019, the production area of Újhartyán was the weakest again, so we applied a complex fertilizer and compared again with better supply possessing areas (Table 3).

Table 2. Doses of fertilizer (kg ha^{-1}) implemented within the framework of the tender (2018)

Settlement (2018)	Amount of fertilizer (kg ha^{-1})
Újhartyán	Untreated
Cegléd	200,00 kg ha^{-1} Ammonal
Vácszentlászló	150,00 kg ha^{-1} Ammonal

Table 3. Doses of fertilizer (kg ha^{-1}) implemented within the framework of the tender (2019)

Settlement (2019)	Amount of fertilizer (kg ha^{-1})
Újhartyán	150,00 kg ha^{-1} 8-24-24 NPK
Cegléd	100,00 kg ha^{-1} Ammonal
Vácszentlászló	100,00 kg ha^{-1} Ammonal

Description of meteorological data

According to recent research, the amount of precipitation required for successful and high-yield soybean cultivation is 300–350 mm and of which require 75% from flowering to early ripening [15, 16, 17, 18]. If there is a drought or falls too concentrated, the yield averages will be much lower because of the unfavourable conditions.

After heavy rains, individual soils find it difficult to drain and retain large amounts of precipitation, nor are the plants able to utilize it immediately, which also negatively affects the production [19, 20]. From the selected production areas, Vácszentlászló has the such as topographic features, on the basis of which it was assumed during the selection of the area that the amount of precipitation required at the critical time will be rained. In 2018 measured precipitation amount at the three different areas during the vegetation is shown in Table 4.

Table 4. Amount of precipitation measured during soybean production (mm) (2018)

Monthly rainfall (mm) (2018)	Újhartyán	Cegléd	Vácszentlászló
April	32	15	32
May	51	27	62
June	94	71	98
July	52	78	36
August	34	47	71
September	68	26	55
October	0	18	0
Total	**331**	**282**	**354**

The critical period of soybeans lasts from flowering to the beginning of ripening, which in Hungary falls in the months of June-July-August. It can be clearly seen that Újhartyán and Cegléd received less rainfall due to the proximity of the Great Plain than Vácszentlászló, which is adjacent to the

Gödöllő hills. Of the precipitation data measured in the critical period, only Vácszentlászló reached the precipitation amount in excess of 200 mm (Table 5), which is less than the required 75% (225 mm).

Table 5. Precipitation measured during a critical period in the three crop areas (mm) (2018)

Precipitation measured during a critical period (mm) (2018)	Újhartyán	Cegléd	Vácszentlászló
June	94	71	98
July	52	78	36
August	34	47	71
Total	**180**	**196**	**205**

In 2019, we repeated the cultivation technology with the above-mentioned parameters and the precipitation data were recorded again until October (until harvest). It can be clearly seen from the data (Table 6-7) that in 2019 our country was characterized by a much drier weather. During the critical period, none of the areas reached the desired 300 mm precipitation, but even the 180 mm precipitation recommended in Hungarian cultivation technology approached only Vácszentlászló.

Table 6. Amount of precipitation measured during soybean production (mm) (2019)

Monthly rainfall (mm) (2019)	Újhartyán	Cegléd	Vácszentlászló
April	25	37	34
May	161	165	165
June	57	65	93
July	77	20	41
August	32	43	37
September	36	34	38
October	11	19	10
Total	**399**	**383**	**418**

Table 7. Precipitation measured during a critical period in the three crop areas (mm) (2019)

Precipitation measured during a critical period (mm) (2018)	Újhartyán	Cegléd	Vácszentlászló
June	57	65	93
July	77	20	41
August	32	43	37
Total	**166**	**128**	**171**

3. Results

The yield results well reflect the effect of fertilizer doses. The yield averages of Újhartyán soybean, which did not apply fertilizer, remained below the expected 2000,00 kg ha^{-1}, therefore we did not expect any outstanding protein content in these soybeans (Table 8). The high-dose (200 kg ha^{-1}) ammonal fertilizer gave better yields than the 150 kg ha^{-1} dose, so it was proved that the 50 kg ha^{-1} nitrogen active ingredient can greatly influence the yield even with a hectic precipitation distribution. Examining the contents (Table 9), it was proved that the nitrogen compounds that can be taken up in the spring contribute to the high protein content, so starter fertilization justified in the case of soybean cultivation in the soils of the studied areas. The highest protein and oil content for all three varieties were provided by the 200 kg ha^{-1} ammonal fertilizer.

Table 8. Yield averages measured per location (kg ha^{-1}) by variety (2018)

Average yield (kg ha^{-1})(2018)	**ES Mentor**	**ES Advisor**	**ES Mediator**
Újhartyán	**1700**	**1500,00**	**1400,00**
Vácszentlászló	2800*	2500*	2700*
Cegléd	3300**	2600*	3100**

p<0,05*; p<0,1

Table 9. Simple measured protein and oil content (%) results with Mininfra, by variety and areas of production (2018)

Protein and oil content (%)(2018)	**ES Mentor**		**ES Advisor**		**ES Mediator**	
	Protein (%)	**Oil (%)**	**Protein (%)**	**Oil (%)**	**Protein (%)**	**Oil (%)**
Újhartyán	**27,9**	**23,9***	**28,0**	**24,2***	**27,7**	**24,3***
Vácszentlászló	33,1*	19,1	32,4*	19,5	30,4*	20,6
Cegléd	36,9**	20,1	34,2*	20,0	35,4**	20,3

p<0,05*; p<0,1**

In 2019, despite less precipitation, the nitrogen fertilizers and in the case of arable land with lower nutrient service ability use of complex fertilizers proved to be important. Újhartyán measured better yield averages in 2019 than in 2018. The yields of the varieties grown in the three areas reached or exceeded the amount of 2000 kg ha^{-1}. In the case of ES Mentor and ES Mediator in Cegléd, while in the case of ES Advisor in Vácszentlászló measured the best yields in 2019 (Table 10).

Table 10. Average yields of different arable land (kg ha^{-1}) by variety (2018)

Average yield (kg ha^{-1})(2019)	**ES Mentor**	**ES Advisor**	**ES Mediator**
Újhartyán	**2200**	**2000**	**2300**
Cegléd	3100**	2200	3300**
Vácszentlászló	2000	2300	2800*

p<0,05*; p<0,1**

Comparing the yield results of the 2018, we measured a significant difference (p <0.05 *; p <0.1 **) between the cultivars of the different arable land. We used the arable land of Újhartyán as a control in 2018, therefore we compared there to the data what we measured in Cegléd and Vácszentlászló. The ES Mentor in Cegléd showed a strongly significant difference (p <0.1 **), while Vácszentlászló deviated to a lesser extent (p <0.05 *) from the result measured in Újhartyán in 2018. In 2019. We compared the results of the areas of Cegléd and Vácszentlászló to the results of Újhartyán again, but we did not experience significant difference to the ES Mentor and ES Advisor, while ES Mediator differed significantly in both areas (p <0.05 *). So, proper nutrient management reduces the difference between yield averages. (Table 11).

Table 11. Demonstration of significant differences in yield results (2018-2019)

Average yield (kg ha^{-1})	ES Mentor (2018)	ES Mentor (2019)	ES Advisor (2018)	ES Advisor (2019)	ES Mediator (2018)	ES Mediator (2019)
Újhartyán	**1700**	**2100**	**1500**	**1900**	**1400**	**2400**
Cegléd	3300**	2600	2600*	2300	3100**	3100*
Vácszentlászló	2800*	1900	2500*	2300	2700*	3100*

p<0,05; p<0,1***

A positive change also observed for the measured to (simple) protein and oil content with Mininfra. In the case of Újhartyán, both parameters improved compare to 2018 and lagged only slightly behind the results of Cegléd and Vácszentlászló in 2019 (Table 12).

Table 12. Simple protein and oil content (%) results by variety and growing area with Mininfra (2019)

Nutritional results (%)(2019)	ES Mentor		ES Advisor		ES Mediator	
	Protein (%)	Oil (%)	Protein (%)	Oil (%)	Protein (%)	Oil (%)
Újhartyán	**33,8**	**19,6**	**33,3**	**19,6**	**36,2***	**20,3**
Vácszentlászló	36,6*	18,9	36,2*	20,4	34,3	20,2
Cegléd	36,0*	19,5	34,6	20,1	32,4	21,6

p<0,05*

Analysing with a feed analysers (NIRS) we obtained even more detailed results (Table 13) and it was seen that the crude protein, crude fat, crude fibre, crude ash content also varied as a function of the applied nitrogen. So, in order to produce a high-quality feed material, it is essential to determine good agronomic practice and production target, which in this case was to achieve a high protein content with an average yield of over 2000 kg ha^{-1}.

Table 13. Content results measured by NIRS feed analysers (g/100g) (2018)

Measurement results with feed analyzer (NIRS) (2018)		Protein g/100g	Fat g/100g	Fiber g/100g	Ash g/100g
Újhartyán	ES Mentor	27,56	25,97	5,41	6,16
	ES Advisor	28,74	25,95	5,84	6,09
	ES Mediator	28,05	25,18	6,49	6,13
Vácszentlászló	ES Mentor	33,35	22,28	4,84	5,57
	ES Advisor	30,71	23,95	5,58	5,8
	ES Mediator	31,76	22,53	5,56	5,28
Cegléd	ES Mentor	36,96	21,14	4,21	5,29
	ES Advisor	34,72	21,4	4,8	5,35
	ES Mediator	33,59	22,23	5,1	5,01

Despite the unfavourable vintage effect (less and concentrated precipitation - see Table 6-7), we measured with the NIRS feed analysers better content values in 2019 compare to 2018. The content of crude fibre and crude ash decreased in the case of Újhartyán in 2019, which confirmed the positive effect of fertilizer application and the fact that these components of soybeans changed only slightly during protein synthesis (Table 14). In 2018, the ES Mentor soybean variety was judge to be the best variety in terms of feeding because with the exception of Újhartyán, high protein and low fibre content were measured in both areas. In the case of full-fat soybeans, low fibre content is desirable, which in 2019 was already much lower in all three areas due to conscious production.

Table 14. Content results measured by NIRS feed analysers (g/100g) (2019)

Measurement results with feed analyzer (NIRS) (2019)		Protein g/100g	Fat g/100g	Fiber g/100g	Ash g/100g
Újhartyán	ES Mentor	33,78	23,13	5,04	5,64
	ES Advisor	33,29	24,85	5,62	5,83
	ES Mediator	36,19	22,44	5,56	5,28
Vácszentlászló	ES Mentor	36,59	21,43	4,68	5,22
	ES Advisor	36,22	21,40	4,80	5,35
	ES Mediator	34,32	20,43	4,78	5,02
Cegléd	ES Mentor	36,03	21,02	4,21	5,28
	ES Advisor	34,62	22,23	5,05	5,45
	ES Mediator	32,44	22,53	5,56	5,32

4. Conclusion

As a result of the research, it can be stated that in the Central Hungarian region the dense row or double grain row spacing (24cm) can be successfully applied in the very early and early ripening groups, and it is recommended to cultivate middle-ripening varieties, if with no branching habitus and the ripening period is less than 135 days, as well as tolerate the distances that less than 36 cm. In order to produce quality raw materials, it is essential to have a well-nutriented arable land and the amount of spring nitrogen fertilizer correctly calculated for it, which in the optimal case does not exceed ~40,00-60,00 kg ha^{-1} of nitrogen active ingredient. With the recommended amount of nitrogen active ingredient, the yield average of 2000,00 -3000,00 kg ha^{-1} can be said to be a suitable amount, but due to the industrial needs of the user, it would be expedient to achieve a higher yield. For this to will be feasible, it is advisable to include additional treatments in production in order to make the most of the variety in all weather conditions, which increases the input costs compared to the application of spring fertilizers but with the higher yields, costs can be recouped [21, 22, 23].

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