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# Comparative study of different soybean genotypes in irrigation technology

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**_SUMMARY_**

*In many places in Hungary, early maturity soybean can be successfully grown. The earlier maturity group of soy which ripened in 110–125 days in most crop areas in Hungary. However, to achieve excellent results, the selection of proper varieties is important too. Successful cultivation is largely dependent on the macro and microclimate of the production area, the nutrient supply of the soil and the cultivation technology. Soybean can be produced in places where the amount of precipitation is right, as the lack of water results in lower yields and deteriorated oil and protein concentrations. In the following study, 2 years (2016 and 2017) are compared to the yield, protein and oil content of the soybeans of the early maturation group in irrigated and non-irrigated treatments. Based on our experiment, it can be stated that, during the irrigation of soybean, oil and protein content and yields did not always change.*

***Keywords:*** *soy, irrigation, yield, protein and oil content*

## *INTRODUCTION*

Soy is a knowledge-intensive culture whose successful production requires modern professional knowledge and up-to-date information. Because of the rapidly changing climatic conditions it is difficult to produce good average yield in Hungary. Farmers have to consciously choose the proper soybean variety, know the nutrient management, water management and physical properties of the soil so that they can provide the plant the best from every aspect. In the absence of this, the expected yield may be missed. Another problem may be the wrongly selected weed control technology, which may cause some types of soy to be burned or, in the worst case, exterminated.

To avoid this, Hungary is increasingly spreading mechanical cross-cutting to reduce the use of chemicals and accelerate the stock closing. After chemical treatment, the development of plants may slow down, therefore, the use of chemicals is not recommended for soy production. It is advisable to check the amount of precipitation before and after sowing, because it is difficult to germination in dry soil. In the case of continuous dry weeks, irrigation shall be performed. Besides the precipitation, soil temperature is a very important factor. If the soil is too cold the seeds are not or hardly to germinate. Ideal soil temperature is 8–16 °C (Balikó, 2018).

Good germination, however, does not guarantee good yield. The risk period is June–July and the first two weeks of August. Must be 160–180 mm rainfall is necessary, during in the critical period of the plant (Zhang and Ling, 2016). This quantity is decreasing in Hungary, which can cause irrigation to be justified. In 2016 and 2017, we continuously recorded the average temperature, rainfall days and monthly precipitation. It was visible at the end of May that drought is high and we needed to irrigate the plant stock, therefore, we watered two times 30 mm. After harvesting, we examined the yields (t $ha^{-1}$), soybean oil and protein content. Compared to the two years, we have obtained interesting results, which do not support the yield-enhancing effect of irrigation on the economic side.

## *MATERIAL AND METHOD*

The study was performed in farming conditions, in Győr-Moson-Sopron County (Hédervár), plots were 1.2 $ha^{-1}$ per kind of soybeans in both years. In order to detect the actual difference, the irrigated and non-irrigated experiment was set up in the same area with a separating band of 3.6 $ha^{-1}$. The subjects of the study were two Austrian (hereinafter called Soy 1 and Soy 2) and two domestic breeds (hereinafter called Soy 3 and Soy 4) belonging to the very early ripening group. We examined the phenophases in both years, but we were did not find big differences. The difference was between of stocks only 1–2 days, but 12–14 days after the sowing appeared the first germ leaf buds, and after at the beginning of June appeared the first flowers, and at the end of July, the first bean pods appeared. We registered the maturation in the second week of August.

The difference was in the number of bean pods that led to the conclusion that the irrigated stocks were more fertile. This is important because these varieties are maturity safe in the areas where maize is grown. The yields correspond to the protein program (> 1 t $ha^{-1}$) and they have a good condition of nutritional characteristics. The moisture, oil and protein contents were measured with a Mininfra Smart SW machine after harvesting. Of the four varieties, the Austrian soybean Soy 1 breed is outstanding, which is suitable for human use and well tolerates the dense row spacing (36 cm). The varieties involved in the experiment were sown in 45 cm row spacing in both years to reduce the amount of herbicides by mechanical cross-cutting. Two days after sowing, we used weed control in both years with Corum + DASH (1.9 l $ha^{-1}$ dose).

Soybean leaves do not burn when using pre-sowing chemicals. Due to the fact that local climatic conditions are more important in keeping the lines clean, the first mechanical cross-cutting was performed 3–4 weeks

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after sowing, in early June. In both years, we chose the driest period for the mechanical cross-cutting and we conducted this action in the morning so that the haze is more useful. Mechanical weed control was performed on each experimental stock because this technology replaces chemical weed control, which is indispensable for qualitative soybean cultivation (Balikó, 2018). Each type of soybean got foliar fertilizer during flowering (early July) because it has been proven that boron, manganese, selenium and a little nitrogen increase the number of flowers and the soybean pods bond. Many are hoping that soy will cover the need for nitrogen through the tubers, and it does not need any additional nitrogen during flowering or soybean pods production, but the reality is that the amount of inadequate nutrients reduces the quantity and quality of the crop. Farmers who do not give nitrogen in the spring before sowing and during flowering do not reach the desired crop quantity and therefore abandon for the soybean production. In both years, the experimental stocks obtained 70 kg $ha^{-1}$ active agent of nitrogen in combination with a maximum of 60 kg $ha^{-1}$ active agent of potassium and 60 kg $ha^{-1}$ active agent of phosphorus, granular format in the spring, one month before sowing (Mandal et al,, 2009). The arable land has medium nitrogen, poor phosphorus and potassium content, neutral pH and weak humus content. Soil type is Fluvisol (HTML[1]).

In the case of irrigated stocks, the first 30 mm irrigation water was applied before foliar fertilization, and after the third day the irrigation it was resumed in 2016 and 2017. The applied nutrients were expected to contribute to a much higher yield than in the non-irrigated area, where in the 9$^{th}$ day following the foliar fertilization we recorded 7 mm precipitation in 2016 (*Table 1*) and 13.5 mm in 2017 (*Table 2*) on 5$^{th}$ day.

*Table 1*

**Rainfall and temperature of vegetation period in 2016**

| Month | 2016 Rainfall (mm) | | | Average temperature (°C) |
|---|---|---|---|---|
| | Rainfall/ month | The number of rainy days | The number of rainy days above 10mm | |
| April | 16 | 3 | 0 | 11.8 |
| May | 78 | 14 | 3 | 15.6 |
| June | 63 | 9 | 2 | 19.8 |
| July | 79 | 9 | 3 | 21.3 |
| August | 51 | 7 | 2 | 19.4 |
| September | 25 | 6 | 0 | 17.9 |
| October | 0 | 0 | 0 | - |
| Total | 312 | 48 | 10 | 17.6 |

During the entire growing season, it rained 312 mm in 2016 and we measured 301 mm precipitation in 2017 (*Table 1–2*). During the critical period (June, July and the first week of August), we registered 159 mm in 2016 and 103 mm in 2017. Soy requires most of the precipitate in the critical period, which fluctuates between 160 and 180 mm (Zhang and Lin, 2016). It is clearly visible (*Table 2*) that, in 2017, this quantity was below the expectations and with the irrigation only 163 mm precipitation achieved during in the critical period. In 2016, the amount of precipitation was much more ideal with irrigation, but we did not measure outstanding and significant difference between the irrigated and non-irrigated treatment. In 2017, the difference between irrigated and non-irrigated areas was already measurable, but there was not as much precipitation as in 2016. During the analysis, we compared the results of the two years in non-irrigated and irrigated fields to make it even more visible how much water to be irrigated to achieve a higher crop yields.

*Table 2*

**Rainfall and temperature of vegetation period in 2017**

| Month | 2017 Rainfall (mm) | | | Average temperature (°C) |
|---|---|---|---|---|
| | Rainfall/ month | The number of rainy days | The number of rainy days above 10mm | |
| April | 38 | 11 | 1 | 11 |
| May | 19 | 8 | 0 | 18 |
| June | 39 | 13 | 0 | 23 |
| July | 57 | 12 | 2 | 23 |
| August | 27 | 11 | 0 | 24 |
| September | 122 | 15 | 6 | 16 |
| October | - | - | - | - |
| Total | 301 | 70 | 9 | 19.2 |

## *RESULTS*

All four genotypes provide very high sheaths (10–12 cm) and the harvest losses are ideally minimal. In 2016 and 2017, we did not find the difference between irrigated and non-irrigated varieties' pod height. Therefore, irrigation does not affect the height of the lower pods. In 2016, we expected that the irrigation to provide a higher yield in comparison with the non-irrigated treatment. Due to the well-calculated nutrient supply and adequate precipitation (in May - 78 mm, see *Table 1*), both stocks developed dynamically. Irrigation commenced at the beginning of flowering (first week of June) and we expected a more dynamic development, but the expected effect was missed, because as a wetter period dawned during the first week, therefore, all stocks developed with the same dynamics. The rainfall of June (63 mm) was prosperous for developing better on the non-irrigated area by the soybeans, and they utilized the water in the area of soil and plants, while the irrigated area of 30 mm and the rainfall of 63 mm have proved to be excessive, because the soil and the plants could not utilize it. The extra water stopped at the surface of the soil and began to gather at certain points as a result of microrelief. In June, we stopped irrigation for leaf fertilization. The downtime lasted for a week (7 days). This amount of time was enough to allow unnecessary water to absorb/evaporate and the area has become accessible (Saseendran et al., 2018). On the 4$^{th}$ day after the

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stoppage, the experimental zone was already in use, so the foliar fertilizer was applied in one turn so that there was no difference between the two groups. Irrigation continued on day 3 after foliar fertilization. However, in the first two weeks of July the weather was rainy in the area, which did not favor the irrigated area. Until 17th of July, a total of 44 mm of precipitation fell (based on its own daily measurements). In the following week, we recorded a drier period, which was sufficient to allow the surface water to penetrate into the ground. Subsequently, we documented a very intense rainfall (until 3 days fell it 30 mm) interval which was not favorable for the irrigated stock. The rainfall of 79 mm in July proved to be too much for the irrigated soybean production in 2016. The registered rainfall was 63 mm in June and 79 mm in July, which may seem to be too small, but the extra irrigation water (60 mm) resulted in 202 mm rainfall, which is too much for the soybean production (Ampofo et al., 2016). We did not test in the irrigated area by the fusarium and sclerotine infection, we assumed that excessive precipitation did not cause any problems. In the irrigated area, each of the 4 soybean genotypes falls over, where the irrigation head was closer and a larger amount of water accumulated, so we reduced area of each treatment with 0.2 $ha^{-1}$ in order to make crop yields comparable. However, crop yields in 2016 (*Table 3*) did not show any significant difference due to the amount of precipitation (Naoki et al., 2017).

*Table 3*

**Effects of irrigation on the yields of soybean genotypes (Hédervár, 2016**

| Varieties | Irrigated | Non-irrigated |
|---|---|---|
| | Yield (t $ha^{-1}$) | |
| Soy 1 | 3.57 | 3.29 |
| Soy 2 | 3.57 | 3.26 |
| Soy 3 | 3.34 | 3.47 |
| Soy 4 | 4.01 | 3.64 |
| $LSD_{5\%}$ | $p > 0.5$ | |

Although we did not test for fusarium and sclerotinia on the irrigated areas, it can be assumed that damaged to the soy stocks the disease and excessive precipitation (Kristofor et al., 2017). However, crop yields in 2016 (*Table 3*) do not show any significant difference due to the amount of precipitation. When we analyze the protein and oil content (*Table 4*), it is obvious that there are differences between the treatments and cultivars, but these do not clearly confirm the effectiveness and the vital importance of irrigation water (Smith et al., 2018).

Comparing the obtained results, it can be seen that the Austrian soybean variety (Soy 1) was excellent in the irrigated area, while in the non-irrigated conditions, only the 3rd best protein content was assured. The home-bred variety Soy 3 assured the highest protein content in non-irrigated conditions. We measured the worst result by the Austrian Soy 2 variety in irrigated and non-irrigated conditions. We have further confirmed that irrigation and an average nutrient supply cannot achieve the maximum protein percentage indicated in the genetic potential. All four varieties were below the desirable 35% protein content in irrigated and non-irrigated conditions, which contribute to a premium feed soy qualification. The oil content was in both cases (irrigated and non-irrigated) 20% or above desired. As a result of the appropriate conditions, the irrigated varieties performed better, but we did not find significant difference. We measured the best oil content by the home-breed Soy 4 variety (*Table 4*) in irrigated conditions, while the best outcome was observed in the non-irrigated conditions of the Austrian Soy 2 variety.

*Table 4*

**Effects of irrigation on the protein- and oil content of soybean genotypes (Hédervár, 2016)**

| Varieties | Irrigated | | Non-irrigated | |
|---|---|---|---|---|
| | Protein content (%) | Oil content (%) | Protein content (%) | Oil content (%) |
| Soy 1 | 31.8 | 24.5 | 28.9 | 21.5 |
| Soy 2 | 28.3 | 24.1 | 26.6 | 22.2 |
| Soy 3 | 29.5 | 24.1 | 30.9 | 20.4 |
| Soy 4 | 29.2 | 24.8 | 29.7 | 21.3 |

The PROFAT value consists of the sum of oil and protein content of soybean. The best quality is 54, while the worst is the 50 PROFAT value. If we look at the average value, it can be stated that the soybean produced in the irrigated area reaches of the 54 PROFAT value. By examining each variety (*Table 5*), it can be seen that in the irrigated area of the Austrian Soy 1 variety and the home-bred Soy 4 reach the upper class, whereas the non-irrigated conditions of Austrian Soy 2 are less than the lowest value (PROFAT value: 50). Consequently, in the first pilot year (2016), we found that market factors such as yield, protein- and oil content are only partly influenced with the irrigation in the better crop year.

*Table 5*

**Effects of irrigation on the PROFAT values of soybean genotypes (Hédervár, 2016)**

| Varietes | Irrigated | Non-irrigated |
|---|---|---|
| | PROFAT value | |
| Soy 1 | 56.3 | 50.4 |
| Soy 2 | 52.4 | 48.8 |
| Soy 3 | 53.6 | 51.3 |
| Soy 4 | 54.0 | 51.0 |

In 2017, more irrigation water was applied, because the amount of precipitation was not intense during the critical period (see *Table 2*) (Tayyaba et al., 2016). Before the irrigation began, the total rainfall was 19 mm in May, which was just enough for initial plant development. We have not experienced the differences in the phenophases whilst benefited on the irrigation

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area, resulting in many flowers and pods turning up in comparison with the non-irrigated areas. We did not change anything in the nutrient supply compared to the previous year, so we can continue to look at the effect of irrigation with another vintage effect. Even after the drought in May, we did not abound to rain. In June only 39 mm and 57 mm of rain fell in July. This is a total of 96 mm, which does not cover the 160 to 180 mm required during the critical period, then neither, when added 60 mm. Consequently, in 2017, it would have needed more irrigation water for the stock because it had a total of 156 mm precipitation, which did not cover the stock. The yield for only two varieties was fully justified by the effect of irrigation (*Table 6*) in 2017.

*Table 6*

**Effects of irrigation on the yields of soybean genotypes (Hédervár, 2017)**

| Varieties | Irrigated | Non-irrigated |
|---|---|---|
| | Yield (t ha$^{-1}$) | |
| Soy 1 | 4.45 | 4.67 |
| Soy 2 | 4.22 | 3.69 |
| Soy 3 | 4.24 | 3.81 |
| Soy 4 | 4.38 | 4.40 |
| $LSD_{5\%}$ | $p > 0.5$ | |

If the irrigated group is examined at the same time, it can be said that all varieties yielded over 4 t ha$^{-1}$, while in the non-irrigated group two varieties were under 4 tons. However, in the non-irrigated group, the Austrian Soy 1 variety performed the best (4.67 t ha$^{-1}$). With these results, irrigation increased yield, which we did not expect, because it did not confirm our hypothesis, according to which irrigation can improve the yield in worse weather conditions (Miransari, 2016). The Austrian Soy 2 and the home-bred Soy 3 in the non-irrigated conditions above the expected yield of 3.5 t ha$^{-1}$, which is currently the desirable yield in the soybean production in Hungary. Examining protein and oil content, unexpected results were obtained (*Table 7*).

*Table 7*

**Effects of irrigation on the protein- and oil content of soybean genotypes (Hédervár, 2017)**

| Varietes | Irrigated | | Non-irrigated | |
|---|---|---|---|---|
| | Protein content (%) | Oil content (%) | Protein content (%) | Oil content (%) |
| Soy 1 | 31.5 | 19.5 | 31.9 | 20.2 |
| Soy 2 | 29.0 | 20.5 | 33.3 | 18.3 |
| Soy 3 | 30.9 | 20.6 | 35.1 | 18.1 |
| Soy 4 | 30.1 | 20.6 | 32.0 | 19.5 |

We have already experienced in 2016 that the oil content increased as a result of irrigation and we were unable to maximize protein content. In 2017, the oil content was not as great as the previous year, although we attributed to more effect with the irrigation water. The best protein results were measured in the Austrian Soy 1 variety, at the expense of the oil content, which did not reach the desired 20%. However, non-irrigated conditions gave good results. The home-bred Soy 3 brought the outstanding 35% protein content, so we could see that other factors, not just irrigation, should be explored. Except for the Austrian Soy 1 variety, the oil content was below 20%, but still higher PROFAT results (*Table 8*) of a non-irrigated conditions with which the Hungarian farmers would be satisfied.

None of the soy varieties reached the desired PROFAT value: 54, while the Soy 3 variety approached it (PROFAT value: 53.2) (*Table 8*), which is a remarkable result. Varieties grown in non-irrigated conditions are therefore classified as PROFAT Class 52, which is a medium grade in the feed industry. Varieties grown under irrigated conditions belong to the poor quality of the PROFAT value classification (PROFAT value: 50), which does not cover the cost of irrigation because the buyer pays little for poor quality.

*Table 8*

**Effects of irrigation on the PROFAT values of soybean genotypes (Hédervár, 2017)**

| Varietes | Irrigated | Non-irrigated |
|---|---|---|
| | PROFAT value | |
| Soy 1 | 51.0 | 52.1 |
| Soy 2 | 49.5 | 51.6 |
| Soy 3 | 51.5 | 53.2 |
| Soy 4 | 50.7 | 51.5 |

## *DISCUSSION*

If we compare the results of two years of irrigation, it is clear that irrigation had a positive effect during the drought period (2017) (*Figure 1*). However, irrigation water spilled during the whole period did not reached the amount required during the critical period (160 - 180 mm) with the fallen precipitation, but in 2017 we managed to increase the yield by 1t, which resulted in the case of each variety more than 4.0 t ha$^{-1}$. In 2016, due to the high precipitation amount, we did not receive any larger sums on the critical period (202 mm), the stock could not utilize it the irrigation water, therefore, yields decreased under 4.0 t ha$^{-1}$.

However, the comparison of the two years revealed a shortcoming. So far only the precipitation and the soil temperature of the sowing were considered and the average temperature during the critical period was not analyzed (Montoy et al., 2017). The development of the soybean pods and the maturation of the seeds and the synthesis of the protein are determined by the amount of heat and precipitation together. In June 2017, this value was 3.2 °C, while it was 1.7 °C in July and 4.6 °C in August in comparison with the average temperatures in 2016, which was more favourable for bloom and pods development (*Figure 2*).

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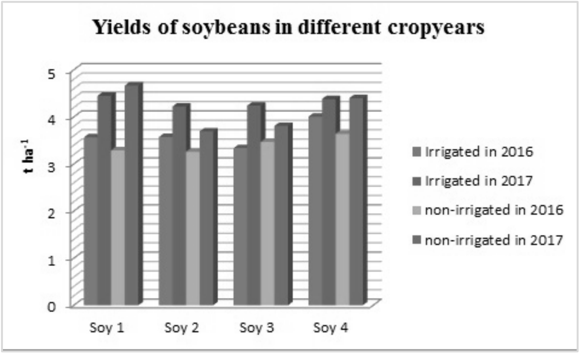
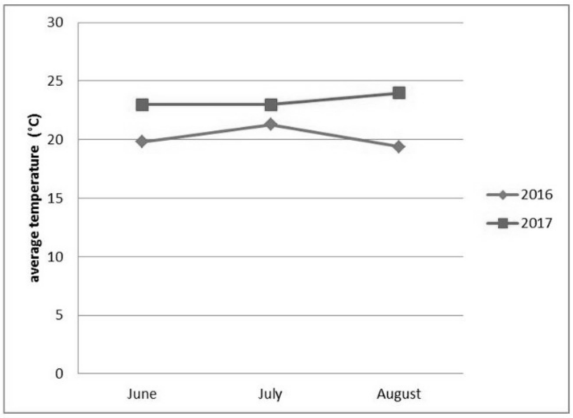
*Figure 1*: **Effects of irrigation on the yields of soybean in different cropyears (Hédervár, 2016-2017)**




In 2017, the average of 24 °C in August improved the protein synthesis, so we obtained better protein content, which is the most important factor in yield for soybeans. The obtained results show that it is not necessary to rely solely on precipitation in the case of soybean production and the microclimate of the crop region is of the greatest importance. Soybean is successful, if everything is optimal and the stock develops properly. Continuous monitoring is essential for soybean cultivation. These four dates in the vegetation period (end of May, beginning of June, end of June, beginning of July, middle of August). However the priority is to keep in mind the needs of the breed and not to the general information that we have learned during presentations, exhibitions (Hasanuzzaman et al., 2016). Continuous monitoring helps to intervene in time in the event of a problem and is more likely to have a good yield than finding a problem which is discovered late and cannot be remedied (Gajić et al., 2018).

*Figure 2*: **The average temperature at the critical period of soybean (°C)**

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