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Economics of site specific crop density in precision sunflower (*Helianthus annuus* L.) production

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SUMMARY

In this research, the crop density of sunflower was examined, which, thanks to the tools available for precision crop production and knowledge of the market environment of sunflower production, best fits the heterogeneous areas of the given production zones and meets the economic requirements. These components together directly influence the effectiveness of sunflower production. In the year of 2021 and 2022, we carried out a site-specific crop density sunflower experiment in two fields with the same soil type, by sowing significantly different amounts of seeds within the given zones. We have established that the sunflower, although a plant with excellent adaptability, reacts sensitively to the place of production and the effect of the year, in zones with heterogeneous productivity, and shows a reaction to sowing with a variable number of seeds per zone, even when examined based on economic aspects.

Keywords: *crop density; economic aspect; productivity zone; profit; sunflower*

INTRODUCTION

In the dry, drought-like production conditions of recent years, the precision cultivation of sunflower is increasingly becoming an object of consideration in the production systems of most farmers. Not only because all the variable costs of 1 ha are lower than the costs of the two largest cereal crops – wheat and corn – but also because without irrigation the sunflower sales revenue exceeds theirs. Last but not least, the sunflower plants require less water than the above-mentioned crops and are more drought-tolerant, and therefore have higher crop production safety. Unfortunately, based on known ecological aspects, it can only be cultivated again every 4 years at the earliest (Frank, 1999).

In any case, the economics of sunflower production should be examined based on the latest ecological-biological-economic information and technologies (Sellye, 1990). Sustainable development is also increasingly important in field crop production and requires adaptation to ecological and economic conditions. It has become essential to take into account the features of the growing area, the needs of plant cultivation and the coordination of the related environmental protection goals. The goal of sustainable production is to maintain the lowest possible environmental impact and economy at the same time (Monoki, 2011).

The sunflower is able to utilize the water resources of the soil extremely well, however, among the factors limiting its yield (Pepo, 2008), if we examine sunflower cultivation in recent years, it is still true that the amount of available water is the primary limiting factor. It is very important that the agrotechnical operations carried out also serve the purpose of making the water resources as accessible as possible to the sunflower (Antal, 1992).

More plants require more water per unit area. The hybrids utilize the soil's water resources with different efficiency, which is greatly influenced by the number of plants sown (Novak, 2012). The optimal number of plants is also an area-, environment-, and hybrid-specific feature (Szabo, 2007), but the soil's productivity, the heterogeneity of our area, the expected yield, the options offered by our seed drill, and the adaptability of the given hybrid also act as modifying factors (Pepo, 2012). Satellite remote sensing and positioning (Moore et al., 1993), the emergence of sensor measurement, geospatial data analysis and processing software and the possibility of access to their use created the foundations of precision crop cultivation (Mesterhazi, 2003). Thanks to the technological developments of precision crop cultivation based on satellite positioning, GIS applications and cultivation tools have become available to farmers, which can be used to significantly increase the efficiency of farming (Milics, 2008).

A technology used relatively long ago in the toolbox of precision crop production is differentiated nutrient application per production zone, however, the results of site-specific controlled seeding (Totin and Pepo, 2016) are still a novelty, especially in the case of sunflower, which, thanks to its excellent adaptability, is less sensitive to the amount of planted seed per hectare. The basis of its usability and efficiency is to achieve a higher yield by increasing the amount of seed applied to the conditions of the production site, or to realize a greater profit by reducing the cost of sowing by reducing it.

The aim of our research is to determine the optimal number of sunflower plants that best fits the heterogeneous growing areas of the given fields and meets the economic expectations, which together directly influence the effectiveness of sunflower

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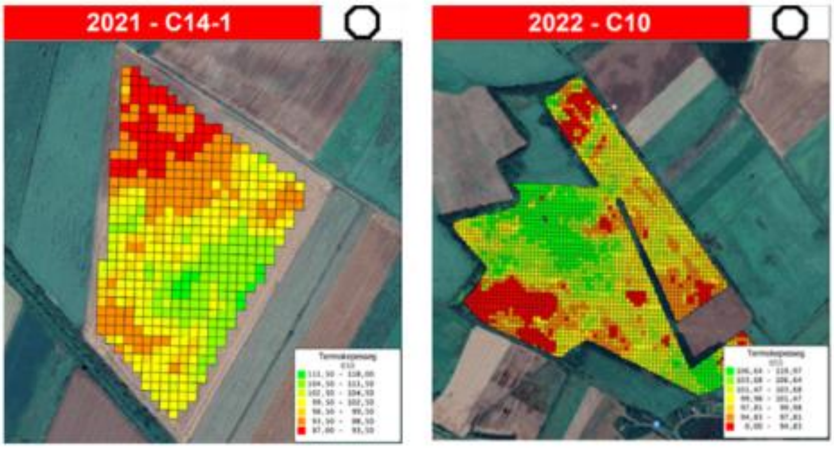
production, through the tools available for precision crop cultivation and the knowledge of the market environment of sunflower production (Pepo, 2018).

MATERIALS AND METHODS

In the year of 2021 and 2022, we carried out a site-specific crop density sunflower seeding experiment in two fields with relatively the same soil properties outside of Egerfarmos (Heves County, Hungary), by sowing significantly different amounts of seeds within the given zones. During the experiment, we examined the characteristics of the growing site, the soil properties of the individual zones, the characteristics of the applied sowing technique (nominal and germinated number of seedlings, uniformity of plant spacing) and the quantity and quality of the crop.

The number-controlled seeding experiments were set up in two bound meadow soil type areas: in the year of 2021 in the area of C14-1 field and in 2022 in the area of C10 field. The productivity zones were created using our own GIS method. When creating the zones, we took into account the geological characteristics of the areas included in the experiment based on the data of the Kreybig soil map, datas of soil samples' tests of the recent years, the data of the space images taken by the Sentinel-2 satellite in the period between 2017–2020, and the yield and height data of the harvesters recorded between 2017–2020 (*Figure 1*).

Figure 1: **Productivity map of fields C14-1 and C10**



After the selection of the field and the productivity zones, we set up three categories of production sites: low, medium and high productivity zones.

The seed number changes of the experimental sowing were carried out automatically by the tractor's on-board computer based on a pre-written sowing plan.

The experimental sowing was planned according to the productivity zone categories as follows: according to the seed manufacturer's recommendation, the seeding rate of the SY Bacardi CLP sunflower hybrid is 55–58,000 seeds ha^{-1}. Accordingly, we considered the proven number of 55,000 seeds ha^{-1} in our cultivation environment as the standard of the plant number experiment. Taking into account the feasibility aspects of the experiment, in each productivity zone, we used three seed number steps repeated in four repetitions (*Figure 2*).

In the low productivity zone, we used the base number of seeds per hectare (55,000) and the number of seeds reduced by 20% (44,000) and 40% (33,000).

In the medium productivity zone, the base number of seeds (55,000) and the number of seeds increased by 20% (66,000) and reduced by 20% (44,000) were used.

In the high productivity zone, we used the base number of seeds (55,000) and the number of seeds increased by 20% (66,000) and 40% (77,000).

Additionally, in the case of all three productivity zones, we also took one strip with a seed number that is not included in the given zone, but is in one of the other two. Thus, 66,000 and 77,000 rows were sown in the low productivity zone, 33,000 and 77,000 in the medium productivity zone, and 33,000 and 44,000 in the high productivity zone in one repetition only to see if there is some unexpected information pops up which experiments are noticeable on the shown figures but does not take into account in this recent research.

In the course of our economic calculations, we evaluated the purity of the harvested sunflower, the moisture and oil content of the cleaned sunflower, and the corrected yield per 1 ha, taking into account practical aspects. The obtained data were formed from the arithmetic mean of the values obtained for the given property of the four repetitions of the given seed number of the given zone.

In the case of both experimental areas – in accordance with the characteristics of the given year – the cultivation technology was the same throughout the area, so only the cost of the amount of seed sown changed due to the change in the number of seeds sown per hectare.

When calculating the incomes, we made our calculations using the pricing form used by BUNGE

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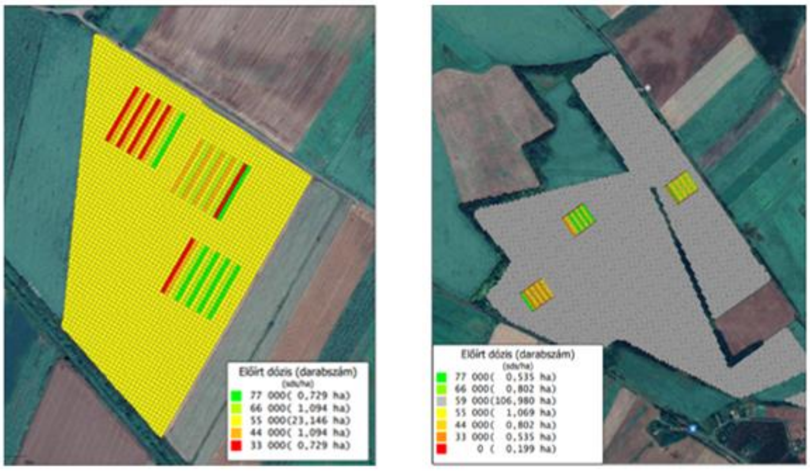
Növényolajipari Zrt., during which the net yield value was based on the market price of the given year, while the bonification of the sunflower content values was based on the basic sunflower values of 98% purity, 9 (m/m)% moisture content and 44 (m/m)% oil content.

Figure 2: **The productivity zones and sowing plan of the experimental sowing of fields C14-1 and C10**

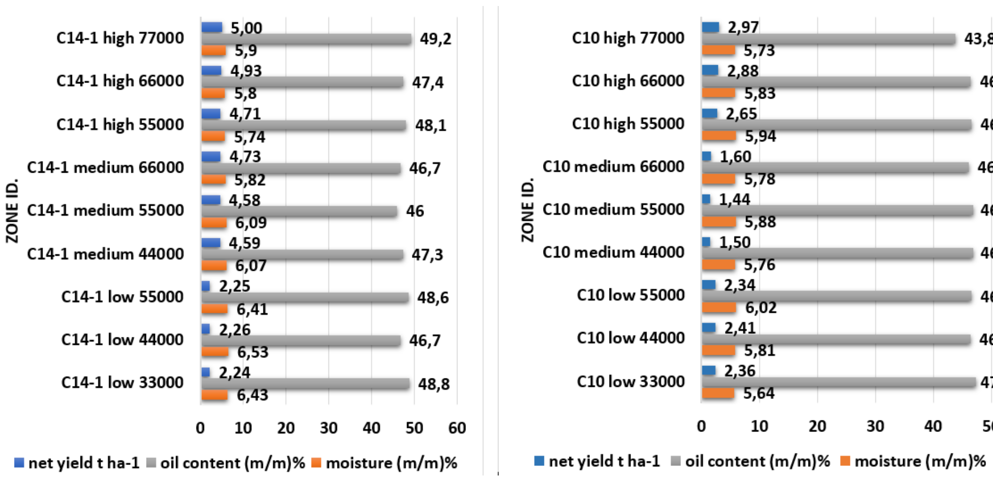


RESULTS AND DISCUSSION

The following results of the harvested sunflower were obtained during the analysis of the data from the sowing experiment of field C14-1 and C10 are shown in *Figures 3.*

Based on our economic calculations, in field C14-1 (*Figure 4*) in the low productivity zone, the highest profit was realized with the number of seeds planted at 33,000 seeds ha^{-1} (HUF 139,179/ha), the reason being that with the lowest seed cost (HUF 17,456/ha), the amount of the yield was barely left from the plantings of 44,000 seeds ha^{-1} (-1%) and 55,000 seeds ha^{-1} (-0.5%). In terms of oil content, it also reached the highest level (48.8(m/m)%), so the highest oil content was able to realize a bonification premium (HUF 24,325/ha), while in terms of moisture content, no significant difference (<0.13%) can be shown between crop density.

Figure 3: **Data of harvested sunflower from the production zones**



In the medium productivity zone, the results show a larger deviation. The highest profit was generated when sowing 66,000 seeds ha^{-1} (HUF 509,709/ha), but it was barely behind the sowing with 44,000 seeds ha^{-1} (HUF 504,231/ha). Examining the yield results, it can be seen that sowing with a number of 66,000 seeds ha^{-1} resulted in the highest yield (4.73 t ha^{-1}), while the result of 55,000 seeds ha^{-1} remained at 3%, and the result of sowing at a number of 44,000 seeds ha^{-1} remained at 3.2% away from it. Based on the oil content, the sowing with the number of 66,000 seeds ha^{-1} (46.7(m/m)%) is lower than the result of the sowing with the number of (47.3(m/m)%), but it is higher than the result of the sowing with the number of seeds ha^{-1} (46(m/m)%).

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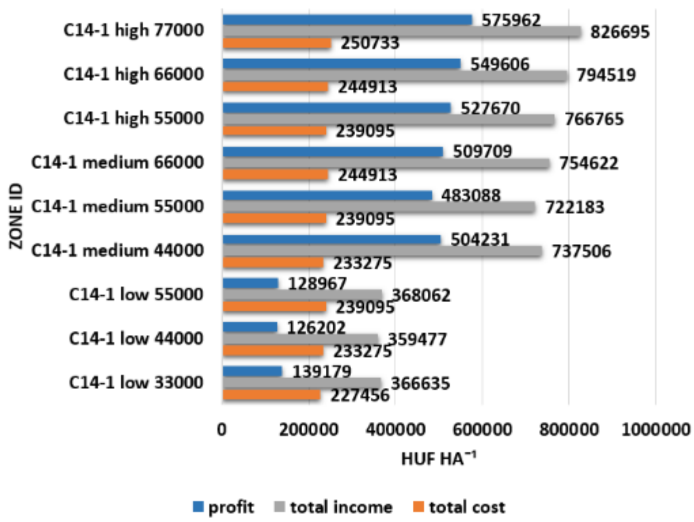
Examining the moisture content, the sowing with 66,000 seeds ha^{-1} showed the lowest result (5.82(m/m)%), which achieved the highest moisture premium (HUF 11,654/ha).

In the high productivity zone, the largest amount of profit was generated in the case of sowing with 77,000 seeds ha^{-1} (HUF 575,962/ha), while a significant correlation was shown as a function of profit and number of plants. As the crop density decreased, the profit also decreased, to HUF 549,606/ha in the case of 66,000 seeds ha^{-1}, and to HUF 527,670/ha in the case of 55,000 seeds ha^{-1}. The cost of the sunflower seed and therefore the total cost also increased, but the extra yield resulted in extra profit. In addition to the yield, the oil content was also the highest (49.2(m/m)%) in the case of sowing with 77,000 seeds ha^{-1}, while the moisture content increased significantly as the number of plants increased.

Figure 4: **Economic evaluation of the production zones of field C14-1**



In the low productivity zone of field C10 (*Figure 5*), the highest profit was shown in the case of sowing with 33,000 seeds/ha (HUF 225,294/ha), it differs only slightly (-0.8%) from sowing with 44,000 seeds ha^{-1} and 10% less this value (HUF 202,497/ha) in the case of 55,000 seeds ha^{-1}. In the case of the three numbers of plants, there is only a small difference (<3%) in terms of the amount of harvested and cleaned sunflower, but there is a more significant difference in the amount and price of sown seed. While this cost is HUF 18,126/ha in the case of 33,000 seeds ha^{-1}, HUF 24,168/ha (+25%) in the case of 44,000 seeds ha^{-1} sowing, and HUF 30,210/ha (+40%) in the case of 55,000 seeds ha^{-1} sowing. The internal value of the harvested and cleaned sunflowers from the 33,000 seeds ha^{-1} sowing area represents an additional value. The oil content reached the highest value (47.3(m/m)%) at this seed number, while the moisture content reached the lowest value (5.64(m/m)%), thereby realizing the highest bonus premium among the revenues, in total HUF 38,141/ha. This value is HUF 30,503/ha (-20%) for sowing with 44,000 seeds ha^{-1}, while HUF 30,824/ha (-19%) for sowing with 55,000 seeds ha^{-1}.

In the medium productivity zone, profit was generated only in the case of sowing with a number of 66,000 seeds ha^{-1}, but even there only to a minimal extent (HUF 3,825/ha), in the case of sowing with a number of plants of 55,000 seeds ha^{-1} -26,999 HUF/ha, while in the case of sowing with a number of seeds ha^{-1} 44,000 a loss of HUF -5,674/ha was realized. The cause of the loss was the low yield, which was 1.6 t ha^{-1} in the case of 66,000 seeds ha^{-1}, 1.44 t ha^{-1} in the case of 55,000 seeds ha^{-1}, and 1.5 t ha^{-1} in the case of 44,000 seeds ha^{-1}. We did not measure any significant differences in moisture content (<0.13%) between the number of plants participating in the experiment, while in terms of oil content, the oil content of the harvested sunflowers was the same in the case of plantings with 44,000 and 55,000 seeds ha^{-1} (46.9(m/m)%), this value was 46.1 (m/m)% in the case of sowing 66,000 seeds ha^{-1}.

In the high productivity zone, the highest profit was achieved by sowing 66,000 seeds ha^{-1}, HUF 333,881/ha. It is noticeable that the highest yield was achieved by sowing with a number of 77,000 seeds ha^{-1} (2.97 t ha^{-1}). However, its quantity was not so large, and the oil content (43.8(m/m)%) was also below the value of the other numbers of plants (55,000 seeds ha^{-1}: 46.6(m/m)%; 66,000 seeds ha^{-1}: 46.5(m/m)%), so it could not compensate for the additional cost of the extra seed quantity sown (HUF 42,294/ha). Due to the mentioned reasons, the profit was HUF 321,460/ha for the number of 77,000 seeds ha^{-1}, while it was HUF 282,177/ha for the 55,000 seeds ha^{-1}. Regarding the yield, it can be observed that the lowest rate (2.65 t ha^{-1}) was obtained by the number of 55,000 seeds ha^{-1}, which is more than 10.7% behind the 77,000 seeds ha^{-1} and 7.98% behind the 66,000 seeds ha^{-1} from the result of sowing. There was no significant difference (<0.22%) in the moisture content of harvested and cleaned sunflowers for the different plant numbers.

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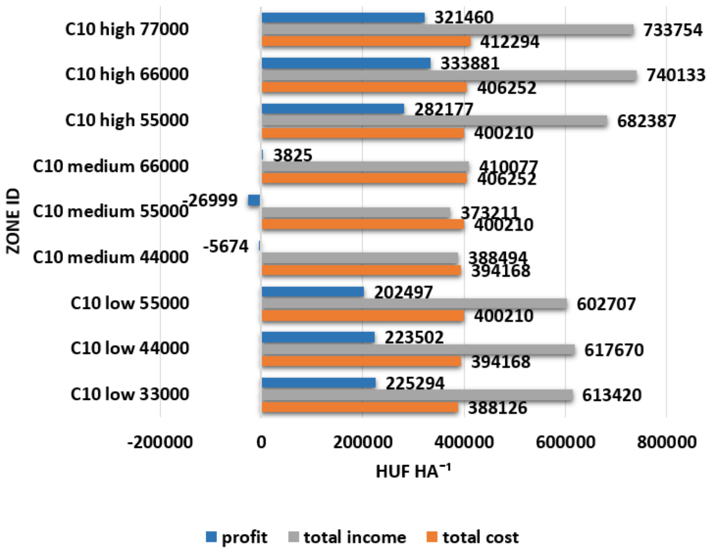
Figure 5: **Economic evaluation of the production zones of field C10**



CONCLUSIONS

We have established that the sunflower, although a plant with excellent adaptability, reacts sensitively to the place of production and the effect of the year, in zones with heterogeneous productivity, and shows a reaction to sowing with a variable number of seeds per zone, even when examined based on economic aspects.

In our two-year studies, we showed that in the low productivity zone – regardless of the vintage effect – sowing with a -40% reduced number of seeds resulted in the highest benefit as a consequence of the yields showing no significant difference and the reduction of seed costs.

In the zone of medium productivity, a larger deviation of the obtained results can be observed. In these areas, the vintage effect prevails more, since these areas fluctuate in yield depending on the vintage. These processes can be observed in a varying way from year to year when examining long-term satellite images, however, the maps showing the heterogeneity of the area are shown as the average of these years. Thus, when planning seeding control, it is worthwhile to take this fact into account when planning the number of seedings. Our investigations also supported this finding, since the justification for the deviation from the standard number of seeds was not clearly proven either in a positive or negative direction. The highest benefit was obtained with a seed quantity of +20% from the standard seed number, however, this result only slightly exceeds the results obtained with the other seed quantities participating in the study. It is also worth taking into account the fact that the seed number reaction of individual hybrids can be different.

Examining the results achieved in the high-productivity zones, on both fields, sowing with an increased number of seeds compared to the standard number of seeds resulted in a higher yield and profit, regardless of the year. In the average rainy and cooler than average year 2021, sowing with a 40% higher number of seeds compared to the standard number of seeds resulted in the highest yield, oil content and thus profit. In the extremely dry and warm year 2022, the number of seeds increased by 40% compared to the standard number resulted in the highest yield. However, the lower oil content of the harvested sunflower seeds had a negative impact on income, and the additional income from the relatively low yield did not cover the additional costs caused by the larger amount of seed demand. In addition to all of these, the highest profit was formed as a result of sowing with a 20% higher number of seeds compared to the standard number of seeds.

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