Investigation of Leaf Surface Development in Strawberry (*Fragaria × ananassa*) under Differential Water Supply Conditions

Szamóca (Fragaria x ananassa) levélfelület-alakulásának vizsgálata eltérő vízellátás mellett

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Abstract: Strawberry (*Fragaria × ananassa*) is undoubtedly one of the most popular berry crops both in Hungary and worldwide. It can be cultivated using several production methods, most commonly under open-field conditions. In open-field cultivation, water supply represents a critical factor, particularly in the context of climate change. The increasing unpredictability of precipitation threatens yield stability. In our experiment, the responses of three strawberry cultivars (Senga S, Honeoye and Kortes) were examined to determine how their leaf surface area and yield were affected by varying water supply levels. Four irrigation regimes were established: optimal irrigation, and 75%, 50% and 40% of the optimal irrigation volume. Leaf surface area exhibited a sensitive response to water deficit; in all cultivars, decreasing irrigation volumes resulted in a reduction of leaf surface area. Yield assessments indicated that even a 25% reduction in water supply caused a drastic yield decline, ranging from 56.1% to 70.6%. Overall, the results demonstrate that adequate water availability is essential for successful strawberry production and for achieving optimal yield levels in the cultivars included in this study.

Keywords: *water supply; strawberry; horticulture; leaf area*

Összefoglalás: A szamóca (*Fragaria x ananassa*) kétségtelenül hazánk és a világ egyik legnépszerűbb bogyós gyümölcse. Termesztésére több mód áll rendelkezésre, gyakran szabadföldi körülmények között történik. Szabadföldi termesztési mód esetében fontos kérdés a vízellátás, elsősorban a klímaváltozás miatt is. A csapadékosság kiszámíthatatlansága veszélyezteti a termésbiztonságot. Kísérletünkben azt vizsgáltuk, hogy 3 különböző szamóca fajta (Senga S, Honeoye, valamint Kortes) levélfelülete és termésmennyisége hogyan változik a különböző vízellátás hatására. Négy vízellátási szint került beállításra: optimális öntözés, valamint az optimális öntözővíz 75, 50 és 40%-a. A levélfelület érzékenyen reagált a vízmegvonásra, az öntözővíz mennyiségének csökkenésével csökkent minden fajta esetében a levélfelület is. A termés mennyiségének vizsgálata során már a 25%-os vízmegvonás is drasztikus, 56,1–70,6%-os természcsökkenés volt megfigyelhető. Összességében megállapítható, hogy a sikeres szamóca termesztéshez és az optimális termésmennyiség eléréséhez optimális vízellátottsági körülmények szükségesek a vizsgálatba vont szamócafajták esetében.

Kulcsszavak: *vízellátás; szamóca; kertészet; levélfelület*

1. Introduction

Due to its shallow root system, strawberry is highly sensitive to soil moisture content (Krüger et al., 1999). Determining the optimal water requirement of strawberry has become a popular and increasingly relevant topic. Identifying cultivars capable of coping with new environmental challenges is of particular importance. For instance, both Klamkowski and Treder (2008) and Bordonaba et al. (2010) examined the effects of water stress on different cultivars and were able to detect significant differences among them. Insufficient irrigation or inadequate water supply results in a reduction in fruit quantity, individual berry weight, and overall yield (Adak et al., 2018). Although nutrient availability also influences fruit production, ensuring adequate fertilization generally represents a less challenging task. At the same time, the effects of irrigation and fertilization on soil nitrate content and the broader environment have attracted increasing scientific attention (Li et al., 2025).

In open-field strawberry production, the most critical months are May, June, and September (Tóth, 1997), as these periods include flowering, fruit set, and the differentiation of next year's flower buds. Optimal yields are achieved when soil pore space is filled to 70–80% capacity (Mohácsy et al., 1965). Previous studies have shown that when irrigation volumes corresponded to 80% of the soil's maximum field capacity, strawberries exhibited vigorous vegetative growth and strong photosynthetic activity (Du et al., 2024). Reasonable and adequately applied irrigation can promote photosynthesis, thereby improving final yields under open-field conditions (Zhang et al., 2018). Conversely, suboptimal irrigation may, to some extent, enhance water-use efficiency in strawberry (Liu et al., 2019). However, when water availability drops below a critical threshold, abscisic acid levels may increase in plant tissues, ultimately reducing yield and fruit quality (Liu et al., 2019).

The aim of our experiment was to investigate three strawberry cultivars widely grown in Hungary—Sonata S, Honeoye and Kortes. We examined how leaf surface area and yield responded to different irrigation levels. Four treatments were applied: optimal irrigation, and water deficit corresponding to 75%, 50%, and 40% of the optimal irrigation volume.

2. Materials and Methods

The experiment was established on 4 April 2023 in the greenhouse of the Department of Agronomy, Institute of Crop Production Sciences, located at Building E of the Hungarian University of Agriculture and Life Sciences, Institute of Agronomy, Georgikon Campus. Three strawberry cultivars (Senga S, Honeoye and Kortes) were compared under four different irrigation regimes. One group received no water stress, while the remaining treatments were subjected to varying levels of water deficit. For each irrigation level and cultivar, three replicates were used, with each replicate planted individually in a plastic pot (30 cm diameter). A peat-based substrate suitable for strawberry cultivation was used as the growing medium, and the soil surface was covered with mulch to reduce evaporative water loss. During the first month, irrigation was applied once per week, based on the amount of water lost through evaporation over the preceding seven-day period. Irrigation was applied from above using a drip irrigation system (Figure 1). To prevent water loss, saucers were placed beneath the pots, ensuring that the supplied water remained available to the plants. Nutrient supply was provided biweekly to ensure that only the effects of water deficit were reflected in the plant traits. During fertilization, each plant received 30 mL of Plantafol 20.20.20 nutrient solution mixed with the irrigation water. Following the establishment of the seedlings, water supply treatments were initiated on 8 May 2023. The plants were divided into four groups: the first received the optimal irrigation volume, while the second, third and fourth groups received 75%, 50% and 40% of the optimal volume, respectively. Leaf surface area was measured weekly using an LI-3000C leaf area meter (Figure 1).

***Figure 1** Leaf area measurement using an LI-3000C device and the installed drip irrigation system.*

3. Results and Discussion

Figure 2 shows the leaf surface area of the three strawberry cultivars (Senga S, Honeoye and Kortes) under four different irrigation treatments. It is clearly visible that the largest leaf areas were recorded under optimal water supply, regardless of cultivar. As irrigation volumes decreased, leaf surface area also declined, with the lowest values observed at 40% of the optimal irrigation level (ranging between 24.9 and 37.3 cm^2 depending on the cultivar).

Even a 25% reduction in irrigation resulted in a significant decrease in leaf surface area: by 47.5% in Senga S ($p = 0.0276$), by 29.7% in Honeoye ($p = 0.0450$) and by 44% in Kortes ($p = 0.0396$). Overall, irrigation at 40% of the optimal volume reduced leaf surface area by 70.8–79.2% compared to the optimal treatment ($p = 0.0037$–0.0085), depending on the cultivar.

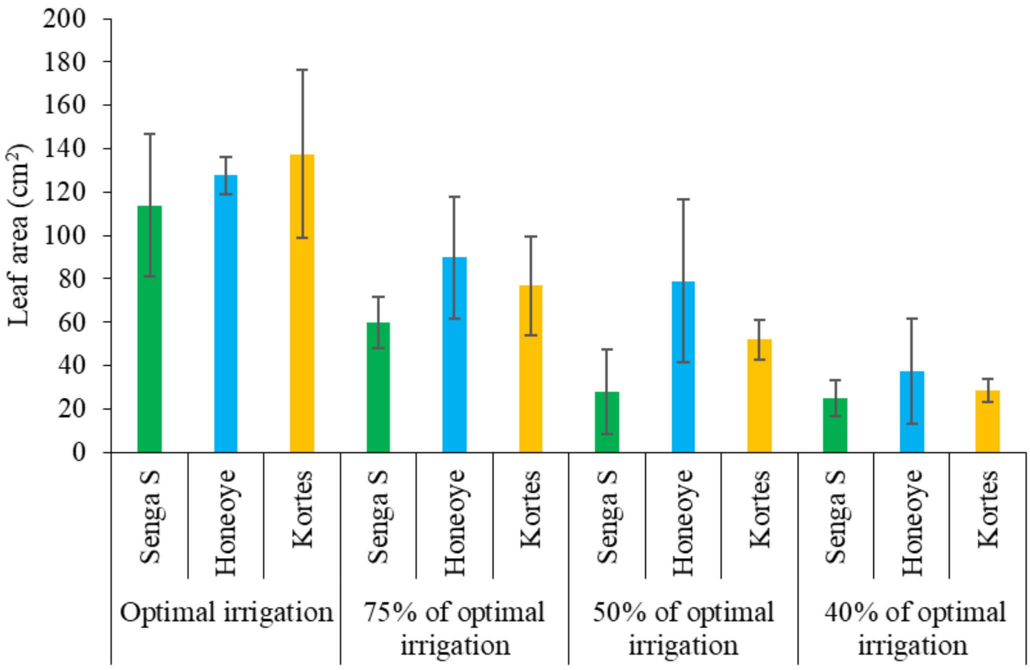

Figure 2 *Leaf surface area of three strawberry cultivars (Senga S, Honeoye and Kortes) under four irrigation treatments (optimal irrigation and 75%, 50% and 40% of the optimal volume)*

The cultivars exhibited differential responses to water deficit. In this experiment, Senga S proved to be the most sensitive to irrigation levels: water reduction relative to the optimal treatment decreased leaf surface area by 47.3–78.1% ($p = 0.0453–0.0103$). Honeoye was the least sensitive cultivar, with leaf surface area reduced by 29.7–70.8% under water deficit ($p = 0.0090–0.0036$). Thus, beyond the effect of irrigation, clear differences among cultivars were also detectable.

Leaf surface area also influenced yield. Figure 3 presents the yield of the three strawberry cultivars (Senga S, Honeoye and Kortes) under different irrigation regimes (optimal irrigation, and 75%, 50% and 40% of the optimal irrigation volume).

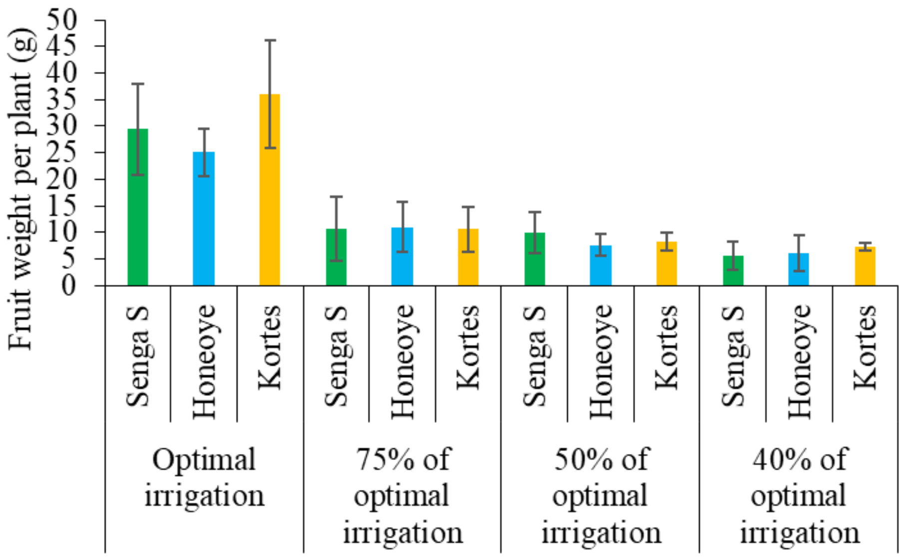

Figure 3 *Fruit yield of three strawberry cultivars (Senga S, Honeoye and Kortes) under four irrigation treatments (optimal irrigation and 75%, 50% and 40% of the optimal volume)*

The highest yield was obtained under optimal irrigation in all three strawberry cultivars examined. Reducing the irrigation volume had a substantial impact on yield, regardless of cultivar. Even a 25% reduction relative to the optimal irrigation level resulted in a drastic yield decline, with fruit weight decreasing by 56.1–70.6% depending on the cultivar ($p = 0.0369–0.0161$). Compared with the 75% irrigation treatment, the 50% water deficit caused a 7.6–31.1% reduction in yield; however, this decrease was statistically significant only in the Honeoye cultivar ($p = 0.0308$). Although lower irrigation intensities affected fruit weight, the differences were not statistically significant.

The assessment of drought tolerance in strawberry cultivars is a relatively well-studied topic. In Poland, Klamkowski and Treder (2008) conducted experiments on the cultivars Elsanta, Elkat and Salut. Similar to our study, frigo plants were planted in a peat-based substrate. In their trial, the Elkat cultivar proved to be the least tolerant to drought. Klamkowski et al. (2015) examined the long-term effects of water stress in three strawberry cultivars, again including Elsanta, alongside Grandrosa and Honeoye. Their study compared a control group with a group subjected to water deficit. The authors found that among the cultivars tested, Elsanta performed the best, while Honeoye showed inferior performance in several parameters. For example, Honeoye exhibited lower photosynthetic activity, the smallest leaf surface area among the cultivars and the least developed root system. Although yield decreased markedly in all cultivars, Honeoye again produced the lowest yields, whereas Elsanta showed the best overall performance.

4. Conclusions

Several publications in the literature address the water supply of strawberry. The results of the present study clearly demonstrate that although the trend associated with water deficit is evident, the magnitude of the response may vary considerably among cultivars. Leaf surface area is related to yield, yet this relationship has been examined less frequently in previous studies. Furthermore, investigations conducted on widely cultivated commercial cultivars remain relatively scarce and therefore fill an important knowledge gap. Our findings may contribute to supporting practical decision-making in cultivar selection for growers.

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