

INVESTIGATING THE RELATIONSHIP BETWEEN WATER/NUTRIENT AVAILABILITY AND YIELD EFFICIENCY IN GRAFTED CHERRY TREES

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Abstract

This research aims to establish the connection between irrigation, fertilization, and economic efficiency in nurseries. This link significantly impacts nursery profitability, as optimal water and nutrient management leads to the production of higher-quality planting material at reduced costs, and consequently, greater profitability. Managing costs related to irrigation and fertilization is a pivotal aspect of achieving economic efficiency in nursery operations. These inputs, while fundamental for plant growth and quality, represent significant expenditures that demand meticulous planning and execution. The aim of academic research in this domain is to quantify these costs and identify strategies for their optimization, ultimately enhancing the profitability and sustainability of nursery enterprises. The research was conducted in a private nursery in northwestern Romania, utilizing planting material obtained from grafting with two cherry cultivars, Katalin and Kordia. Four irrigation rates and four fertilization levels were applied as technological elements. Considering the economic indicators for the two cultivars, a small variation in the cost price was observed, ranging from 5.79 Ron/tree for the Katalin cultivar down to 5.07 Ron/tree for Kordia grafted trees. Correspondingly, the profit margin varied from 38.08% to 57.72%. Thus, the profit per grafted tree for the two cultivars was between 2.21 and 2.93 Ron.

Key words: water, primary macronutrients, nursery, economic efficiency, fruit trees production.

INTRODUCTION

Achieving profitability in a nursery is crucial for its ongoing viability and growth. It reflects the disparity between the total income earned from selling plants and the overall production and operational expenses. A profitable nursery not only provides financial benefits for its owners but also enables reinvestment in modernization, expansion, and enhancements in product quality. The profitability of a nursery is greatly and directly affected by the technological factors used. While investing in technology may come with higher upfront costs, it typically leads to increased revenue, lower operational expenses, and improved quality of products, resulting in better long-term profitability (Wallin, 2020). Irrigation in a nursery provides the essential water needed for the proper growth and development of seedlings. The significance of irrigation in a nursery is crucial, acting as a key horticultural practice that directly supports the biological and economic viability of plant propagation and cultivation. Irrigation

guarantees the accurate delivery of the ideal amount of water to plants during key growth phases, thus supporting crucial physiological functions like photosynthesis, nutrient absorption, and cell turgor, which are all essential for robust and healthy development (Smith, 2022). Water needs differ based on factors such as species, growth stage, type of substrate or soil, and environmental conditions like temperature, humidity, and wind. From a business standpoint, managing irrigation effectively leads to the cultivation of strong, evenly sized, and visually attractive nursery plants. Plants that suffer from a lack of water will show restricted growth, inferior leaf quality, and a generally less appealing appearance, which necessitates longer cultivation times to reach marketable sizes and quality. This, in turn, raises production expenses and delays the generation of revenue (Fasani et al., 2025). Consequently, optimizing irrigation practices is not merely a matter of plant survival but a critical factor influencing the marketability of the material, the efficiency of resource

utilization, and ultimately, the financial profitability of the nursery enterprise (Jäger, 2021). Insufficient water (water stress) hampers growth, disrupts photosynthesis, decreases plant turgor, and increases vulnerability to diseases and pests. On the other hand, too much water can cause root suffocation, the onset of diseases (such as root rot), and the leaching of nutrients (Thomas, 2021). Water-stressed plants will be smaller, less attractive, and will require a longer growing period to achieve the desired size and quality (Ghorbanian et al., 2025). Fertilization is especially important in a nursery because it is the main source of vital macroelements (e.g. G. microelements - such as potassium, phosphorus, and nitrogen) and microelements to plants in amounts and ratios specifically designed for the best possible growth and development. Key physiological processes such as root proliferation, shoot elongation, foliar expansion, and the overall structural integrity and resilience of the plant are all directly impacted by nutrient availability (Ferrara et al., 2025). Suboptimal plant development is always the consequence of inadequate or unbalanced fertilization regimes, which show up as obvious nutrient deficiencies (e.g. G. reduced vitality, stunted growth, chlorosis, and weakened general health). Such malnourished seedlings are naturally less appealing to potential customers and need to be cultivated for a longer period to satisfy market requirements, which lengthens production cycles and raises operating expenses (Mayer, 2019). On the other hand, overfertilization can result in nutrient toxicities, which can harm plants and cause root burn. It can also pose environmental hazards by leaking nutrients into runoff or groundwater, which calls for careful management. Economically speaking, producing high-quality planting material—which is defined by strong growth, a well-developed root system, and the lack of stress symptoms - requires careful fertilization (Khan et al., 2025). Due to higher post-planting survival rates, such superior quality stock fetches higher market prices, improves customer satisfaction, and eventually lowers nursery losses. Furthermore, nutrient use efficiency is greatly increased by sophisticated fertilization techniques like controlled-release fertilizers and fertigation, which delivers soluble nutrients through the irrigation system. By minimizing

nutrient losses, lowering application frequency, and optimizing labour and material costs, these techniques directly improve the nursery's financial success and environmental sustainability. The effective control of production costs, which calls for the prudent use of resources, is a key component of profitability. For example, using sophisticated fertigation and drip irrigation systems greatly reduces the amount of water and fertilizer used. Significant savings are achieved by precisely applying water and nutrients to the root zone, minimizing losses from evaporation and leaching (Megh, 2021). Additionally, automating these procedures lessens the need for manual labour, which is a significant operational expense in any nursery. Utilizing controlled-release fertilizers optimizes labour and material costs by reducing application frequency and promoting effective nutrition. In the end, a fruit tree nursery's success depends on careful operational execution, strategic planning, integrating contemporary technologies, optimizing resources, and keeping a laser-like focus on quality.

The primary objective of this research is to comprehensively analyse the economic efficiency of fruit tree production within a nursery setting, specifically under varying conditions of irrigation and fertilization. This investigation aims to establish the intricate relationship between these critical technological inputs and the overall profitability and sustainability of nursery operations. By quantifying the direct and interactive effects of water and nutrient management on both production costs and generated revenues, the research seeks to determine optimal practices that lead to the cultivation of superior quality planting material at reduced unit costs. Ultimately, the goal is to provide evidence-based insights that can inform strategic decision-making for nursery managers, enabling them to enhance resource use efficiency, maximize profit margins, and foster long-term economic viability in the horticultural sector.

MATERIALS AND METHODS

This research was conducted at a private nursery in the north-western region of Romania, under its specific soil and climatic conditions. The study employed a trifactorial experimental design to analyse key influences on nursery

operations. Irrigation served as the primary experimental factor, with the cultivar as the secondary factor, and fertilization as the tertiary factor. For fertilization, three distinct amounts of NPK were applied: 50 kg of N₈P₈K₈, 100 kg of N₁₆P₁₆K₁₆, and 150 kg of N₂₄P₂₄K₂₄. The four irrigation rates employed were non-irrigated, and irrigation at 10 mm, 20 mm, and 30 mm. For grafting, dormant buds from the Kordia and Katalin cherry cultivars were used.

A highly regarded sweet cherry cultivar, the Kordia cherry has become increasingly popular among amateur gardeners and commercial farmers. Its outstanding fruit quality and appealing tree traits make it especially prized. Kordia cherries are very big; they usually weigh 10-12 g and measure 28-30 mm. When completely mature, they have a gorgeous dark crimson to black, glossy skin and a heart-shaped, prominent apex. The flesh is dark crimson and firm. This cherry cultivar is well known for their excellent, sweet, and fragrant flavour; they are frequently characterized as having a strong scent and a lengthy, fulfilling finish. They provide a delicate acidity and a nice mix of sweetness. Because of its firm flesh, the fruit is very attractive when eaten fresh. Its good transportability and capacity to be stored in cold circumstances for several days are also factors. The Katalin cherry cultivar is a lesser-known yet promising sweet cherry cultivar. Although it is not as widely available as Kordia, it has several advantageous qualities that make it desirable for processing as well as fresh eating. To satisfy the current market demands for delicious cherries, Katalin usually produces huge fruits, frequently measuring 26-28 mm or even larger. It is renowned for its high sugar content, good firmness, and well-balanced sugar-to-acid ratio, all of which contribute to its superb flavour. Katalin's low susceptibility to rain-induced fruit cracking is a major benefit as it preserves fruit quality and lowers post-harvest losses (Blind, 2020).

RESULTS AND DISCUSSIONS

Regarding the economic efficiency indicators for different irrigation norms (Table 1), it is observed that the cost price per tree varied from 4.23 Ron for the 30 mm norm, up to 10.62 Ron

for the non-irrigated variant. Similarly, the profit margin ranged from -24.67% for trees grown under non-irrigated conditions to 89.13% for trees obtained with the 30 mm irrigation norm.

Table 1. Economic efficiency indicators for grafted fruit tree production per experimental factor

Factors	Grafted trees/ha	Income (Ron/ha)	Costs (Ron/ha)	Profit (Ron/ha)	Profit margin/ha (%)	Cost price (Ron/tree)	Profit (Ron/tree)
Irrigation							
0 mm	19950	159600	211860	-52260	-24.67	10.62	-2.62
10 mm	42023	336184	216759	119425	55.10	5.16	2.84
20 mm	46230	369840	217498	152342	70.04	4.70	3.30
30 mm	51594	412752	218238	194514	89.13	4.23	3.77
Cultivar							
Katalin	37297	298374	216089	82285	38.08	5.79	2.21
Kordia	42602	340818	216089	124729	57.72	5.07	2.93
Fertilization							
N ₀ P ₀ K ₀	17513	140104	214679	-74575	-34.74	12.26	-4.26
N ₈ P ₈ K ₈	42900	343200	214919	128281	59.69	5.01	2.99
N ₁₆ P ₁₆ K ₁₆	49052	392416	215159	177257	82.38	4.39	3.61
N ₂₄ P ₂₄ K ₂₄	50333	402664	215399	187265	86.94	4.28	3.72

Therefore, considering the unilateral effect of irrigation, there is a gradual increase in the economic efficiency of grafted tree production as the irrigation rate changes. This is associated with a 15% increase in the profit margin between the 10 mm and 20 mm rates, and a further 19% increase when irrigation is supplemented from 20 mm to 30 mm. Analysing the economic indicators for the two cultivars, there is a small variation in the cost price, ranging from 5.79 Ron/tree for the Katalin cultivar down to 5.07 Ron/tree for Kordia grafted trees. Correspondingly, the profit margin varies from 38.08% to 57.72%. As a result, the profit per grafted tree for the two cultivars was 2.21-2.93 Ron. Considering the unilateral effect of fertilization, the cost price ranged between 4.28 Ron/tree for the soil fertilized with 24% NPK and 12.26 Ron/tree for the unfertilized soil. Furthermore, the profit and profit margin associated with the three fertilization levels were proportional to the cost price, recording values of 2.99-3.72 Ron/tree and 59.69-86.94%, respectively. In the case of the non-irrigated variant, expenses were higher than revenues, resulting in a negative profit margin. The cultivar's effect on the economic efficiency of grafted tree production was higher for un-irrigated soil, with a profit variation from 16,716 Ron/ha for the Kordia cultivar to 108,140 Ron/ha for the Katalin cultivar (Table 2).

Table 2. Economic efficiency indicators for grafted cherry trees production of the two cultivars under different irrigation conditions

Experimental factors	Grafted trees/ha	Income (Ron/ha)	Costs (Ron/ha)	Profit (Ron/ha)	Profit rate/ha (%)
0 mm					
Katalin	22855	182840	211860	-29020	-13.70
Kordia	17046	136368	211860	-75492	-35.63
10 mm					
Katalin	38357	306856	216759	90097	41.57
Kordia	45690	365520	216759	148761	68.63
20 mm					
Katalin	39857	318856	217498	101358	46.60
Kordia	52603	420824	217498	203326	93.48
30 mm					
Katalin	48118	384944	218238	166706	76.39
Kordia	55070	440560	218238	222322	101.87

When using a 30 mm irrigation rate, the economic efficiency of grafted tree production showed no differences between the cultivars. The profit margin for non-irrigated conditions ranged from 7.89% for the Kordia cultivar to 51.04% for the Katalin cultivar. However, under the effect of the 30 mm irrigation rate, it reached a value of 109.47% for both cultivars. Irrigation had a greater influence on the economic efficiency of grafted tree production for the Kordia cultivar, leading to a 104% increase in profit margin with the 10 mm rate and a 129-147% increase with the 20-30 mm rates. For the Katalin cultivar, irrigation with 10-20 mm rates generated a 55-60% increase in profit margin,

while the 30 mm irrigation rate led to a 90% increase in profit margin. Considering the economic efficiency indicators for grafted tree production (Table 3), it is observed that across the entire experiment, the cost per tree varied from 3.81 Ron for the variant fertilized with 24 % NPK on soil irrigated with a 20 mm rate, up to 18.94 Ron for the 10 mm irrigation rate on unfertilized soil. Consequently, the profit margin showed a variation ranging from -57.75% for the variant combining the 10 mm rate with N₀P₀K₀ (no fertilizer) to 109.84% for the N₂₄P₂₄K₂₄ variant irrigated with a 20 mm rate.

Table 3. Economic efficiency indicators for grafted cherry trees production under different irrigation and fertilization conditions

Experimental factors	Grafted trees/ha	Income (Ron/ha)	Costs (Ron/ha)	Profit (Ron/ha)	Profit margin/ha (%)	Cost price (Ron/tree)	Profit (Ron/tree)
0 mm							
N ₀ P ₀ K ₀	0	0	211500				
N ₈ P ₈ K ₈	20072	160576	211740	-51164	-24.16	10.55	-2.55
N ₁₆ P ₁₆ K ₁₆	28777	230216	211980	18236	8.60	7.37	0.63
N ₂₄ P ₂₄ K ₂₄	30953	247624	212220	35404	16.68	6.86	1.14
10 mm							
N ₀ P ₀ K ₀	11428	91424	216399	-124975	-57.75	18.94	-10.94
N ₈ P ₈ K ₈	45428	363424	216639	146785	67.76	4.77	3.23
N ₁₆ P ₁₆ K ₁₆	55143	441144	216879	224265	103.41	3.93	4.07
N ₂₄ P ₂₄ K ₂₄	56094	448752	217119	231633	106.68	3.87	4.13
20 mm							
N ₀ P ₀ K ₀	19492	155936	217138	-61202	-28.19	11.14	-3.14
N ₈ P ₈ K ₈	52143	417144	217378	199766	91.90	4.17	3.83
N ₁₆ P ₁₆ K ₁₆	56143	449144	217618	231526	106.39	3.88	4.12
N ₂₄ P ₂₄ K ₂₄	57143	457144	217858	239286	109.84	3.81	4.19
30 mm							
N ₀ P ₀ K ₀	39139	313112	217878	95234	43.71	5.57	2.43
N ₈ P ₈ K ₈	53958	431664	218118	213546	97.90	4.04	3.96
N ₁₆ P ₁₆ K ₁₆	56143	449144	218358	230786	105.69	3.89	4.11
N ₂₄ P ₂₄ K ₂₄	57143	457144	218598	238546	109.13	3.83	4.17

In the absence of irrigation, fertilization led to an increase in the profit margin from 8.60% with the 16 % NPK level to 16.68% for the 24 % NPK level. This also translated to an increase in profit from 0.63 to 1.14 Ron/tree. For the unfertilized variant, the grafted trees did not reach the required vigour to be sold. With a 10 mm irrigation rate, the absence of fertilization resulted in a negative profit margin. However, under the effect of fertilization, the profit margin ranged from 67.76% to 106.68%, corresponding to a profit of 3.23-4.13 Ron/tree. When using a 20 mm irrigation rate, the profit margin varied from 91.90% for the variant fertilized with 8 % NPK to 109.84% for the 24 % NPK level, yielding profits of 3.83-4.19 Ron/tree. Under the effect of a 30 mm irrigation rate, fertilization had a lesser influence on the economic efficiency of grafted tree production compared to other irrigation rates. This is because the profit margin recorded a positive value of 43.71% on unfertilized soil. For the three NPK levels, the profit margin was 97.90-109.13%, and the profit was 3.96-4.17 Ron/tree. For unfertilized soil, only 30 mm of irrigation resulted in a positive profit margin, yielding a profit of 2.43 Ron/tree. When fertilizing with 8 % NPK, 10 mm of irrigation led to a significant increase in the profit margin from -24.16% to 67.76% and a 5.78 Ron increase in profit per tree. Increasing the irrigation rate from 10 mm to 20 mm resulted in a substantial 24.14% increase in the profit margin and a 0.6 Ron increase in profit per tree. However, changing the irrigation rate from 20 mm to 30 mm had a smaller impact on the economic efficiency of grafted tree production, evidenced by a 6% increase in the profit margin

and a 0.16 Ron increase in net profit per tree. Under the effect of 16% NPK fertilization, a substantial increase in the profit margin of approximately 95% was observed with the 10 mm irrigation rate. Subsequently, increasing the irrigation rate led to a smaller positive variation in the profit margin of 2.5-3% and a 0.04-0.05 Ron increase in net profit per tree. With 24% NPK fertilization, irrigation significantly boosted profit by 90-93% and reduced the cost price by approximately 3 Ron/tree. Changing the irrigation rate from 10 mm to 20 mm resulted in a 3.2% increase in the profit margin and a 0.06 Ron increase in profit per tree. In contrast, increasing the irrigation rate from 20 mm to 30 mm had a very limited impact on the economic indicators of grafted tree production. When it comes to the interaction between cultivars and fertilization (Table 4), it can be observed that the cultivar's effect on the economic efficiency of grafted tree production was more pronounced in unfertilized soil. This was associated with a profit margin variation from -72.85% for the Katalin cultivar to 3.37% for the Kordia cultivar. The differences between cultivars in terms of economic efficiency indicators decrease as the applied fertilization level increases. Thus, under the effect of the 24 % NPK treatment, the profit margin for the two cultivars was between 86.67% and 87.20%. Fertilization had a greater influence on the economic efficiency of grafted tree production for the Katalin cultivar, leading to a 132.95% increase in profit margin with the 8 % NPK level and a 153.66-159.52% increase with the 16-24 % levels. For the Kordia cultivar, fertilization with 8 % NPK resulted in an approximate 56% increase in profit margin.

Table 4. Economic efficiency indicators for grafted cherry trees production of the two cultivars under different fertilization conditions

Experimental factors	Grafting trees/ha	Income (Ron/ha)	Costs (Ron/ha)	Profit (Ron/ha)	Profit rate/ha (%)
N ₀ P ₀ K ₀					
Katalin	7286	58288	214679	-156391	-72.85
Kordia	27740	221920	214679	7241	3.37
N ₈ P ₈ K ₈					
Katalin	43011	344088	214919	129169	60.10
Kordia	42790	342320	214919	127401	59.28
N ₁₆ P ₁₆ K ₁₆					
Katalin	48629	389032	215159	173873	80.81
Kordia	49474	395792	215159	180633	83.95
N ₂₄ P ₂₄ K ₂₄					
Katalin	50262	402096	215399	186697	86.67
Kordia	50404	403232	215399	187833	87.20

Supplementing fertilization from 8 to 16% NPK led to a significant 24.67% increase in the profit margin. However, changing the level from 16 to 24% NPK had a smaller impact, showing only a 3.25% influence on the economic efficiency of grafted tree production. Regarding the cost and profit for grafted trees of the two cultivars under different irrigation conditions (Figure 1), it can be observed that for the Katalin cultivar, the cost price ranged from 4.54 Ron with a 30 mm irrigation rate to 9.27 Ron under non-irrigated conditions.

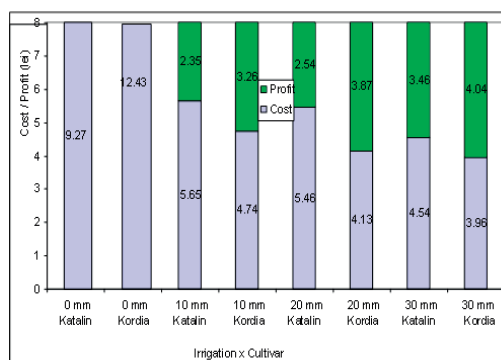


Figure 1. Cost and profit for grafted trees of the two cultivars under different irrigation conditions

This correlated with profits of 2.35-3.45 Ron/tree. For the Kordia cultivar, the cost price varied from 12.43 Ron in the absence of irrigation to 3.96 Ron with a 20 mm irrigation rate, corresponding to profits of 3.26-4.04 Ron/tree. Under non-irrigated conditions, the cost price for Katalin grafted trees was lower than for Kordia. However, with 10-30 mm of irrigation, the profit for the Kordia cultivar was higher by 0.91-1.33 Ron/tree, with the highest value occurring under 20 mm irrigation. Fertilization had a greater influence on the economic efficiency of grafted tree production for the Katalin cultivar, showing a significant 83% reduction in cost price compared to the unfertilized variant (Figure 2).

Supplementing fertilization from 8 to 16 % NPK led to a 0.58 Ron increase in profit per tree, while changing the level from 16 to 24 % NPK did not significantly affect the cost price per tree.

For the Kordia cultivar, a significant 35% reduction in cost price was observed when fertilized with 8% NPK, compared to the unfertilized variant.

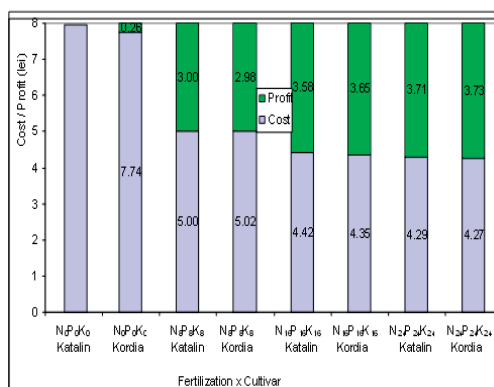


Figure 2. Cost and profit for grafted trees of the two cultivars under different fertilization conditions

Subsequently, increasing the level from 8 to 16% NPK generated a 25% increase in profit per tree, while supplementing fertilization from 16 to 24% NPK resulted in a smaller 2.2% variation. The cultivar's effect on the efficiency of grafted tree production was more pronounced in unfertilized soil. This was associated with a cost price variation from 29.46 Ron/tree for the Katalin cultivar down to 7.74 Ron/tree for the Kordia cultivar. The differences in profit per grafted tree between cultivars decreased with increased fertilization. Thus, under the effect of fertilization, profits varied from 2.98-3.0 Ron/tree for the 8% NPK level, up to 3.71-3.73 Ron/tree with the 24% NPK level. Considering the cost estimates for various fertilization treatments under non-irrigated conditions, it is observed that manual labour accounts for the largest share of total expenses, at 55.32-55.51%. This is followed by material costs at 41.32-41.52%, and mechanical operations at 3.16-3.17%. Under a 10 mm irrigation regime, material costs contributed 54.26-54.44% to total costs. This was associated with a 42.46-42.65% contribution from manual labour expenses and 3.9-3.10% from mechanical operations. With a 20 mm irrigation rate, applying different fertilization variants resulted in a cost structure composed of 54.07-54.25% for manual labour costs, 42.66-42.85% for material costs, and 3.08-3.09% for mechanical operations. Finally, with a 30 mm irrigation rate, material costs contributed 53.89-54.07% to total costs. This was associated with a 42.85-43.04% contribution from manual labour expenses and 3.07-3.08% from mechanical operations.

CONCLUSIONS

The profit margin for different irrigation rates ranged from 55.10% for trees irrigated with a 10 mm rate to 89.13% for trees grown under a 30 mm irrigation rate. This shows a gradual increase in the economic efficiency of grafted tree production as the irrigation rate changes, associated with a 15% increase in the profit margin between the 10 mm and 20 mm rates, and a further 19% increase when irrigation is supplemented from 20 mm to 30 mm. Considering the economic indicators for the two cultivars, there's a small variation in the cost price, from 5.79 Ron/tree for the Katalin cultivar down to 5.07 Ron/tree for Kordia grafted trees. Correspondingly, the profit margin varies from 38.08% to 57.72%. As a result, the profit for the two cultivars was 2.21-2.93 Ron/grafted tree. Regarding fertilization, the cost price ranged between 4.28 Ron/tree for soil fertilized with 24 % NPK and 12.26 Ron/tree for unfertilized soil. Furthermore, the profit and profit margin associated with the three fertilization levels were proportional to the cost price, recording values of 2.99-3.72 Ron/tree and 59.69-86.94%, respectively. In the case of the non-irrigated variant, expenses were higher than revenues, resulting in a negative profit margin. Irrigation had a greater influence on the economic efficiency of grafted tree production for the Kordia cultivar, leading to a 104% increase in the profit margin with the 10 mm rate and a 129-147% increase with the 20-30 mm rates. For the Katalin cultivar, irrigation with 10-20 mm rates generated a 55-60% increase in the profit margin, while the 30 mm irrigation rate led to a 90% increase in the profit margin. In the absence of irrigation, fertilization led to an increase in the profit margin from 8.60% when applying the 16% NPK level to 16.68% for the 24 % NPK level, corresponding to a profit increase from 0.63 to 1.14 Ron/tree. For the unfertilized variant, the grafted trees did not reach adequate vigour for commercialization. Fertilization had a greater influence on the economic efficiency

of grafted tree production for the Katalin cultivar, causing a profit margin increase of 132.95% with the 8% NPK level, and 153.66-159.52% with the 16-24% levels. For the Kordia cultivar, fertilization with 8 % NPK resulted in an approximate 56% increase in the profit margin. Supplementing fertilization from 8 to 16% NPK generated a significant 24.67% increase in the profit margin, while changing the level from 16 to 24% NPK had a lesser influence of 3.25% on the economic efficiency of grafted tree production. From an economic efficiency standpoint, the recommended options are those involving fertilization with 24% NPK on soils irrigated with 20-30 mm norms. These conditions allowed for profit margins of 109.13-109.84%, yielding profits of 4.17-4.19 Ron per tree.

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