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Cultivation technology and farm management issues of apricot production under the impacts of climate change

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ABSTRACT

Apricot cultivation is growing in importance worldwide, especially in regions where gaps in the fresh market supply can be exploited. Hungary is located at the northern edge of economical cultivation area, which presents both challenges and opportunities. Yields in Hungary's 5,300 hectares of apricot production area shows a deviation from 6,000 to 34,000 tons, mainly due to spring frosts and outdated technology. At the same time, due to the late ripening and excellent nutritional value of domestic fruit, premium prices can be achieved on the market, especially for exports to Western Europe. Frost protection is a decisive factor from an economic point of view. In the case of high production standards (intensive cultivation), even less modern, semi-intensive apricot orchards show acceptable income-generating capacity and profitability, while orchards with much higher capital requirements, equipped with crop protection technologies, either in part or in whole, have a much higher income-generating capacity. Based on the results of the investment analysis, at the end of its useful life cycle, a semi-intensive orchard generates an NPV of almost EUR 25,400 per hectare, a super-intensive orchard generates 2.5 times that amount, and a super-intensive orchard equipped with frost protection generates 3.6 times that amount.

KEYWORDS

apricot production, frost protection systems, semi-intensive orchard, super-intensive orchard, cost benefit analysis

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INTRODUCTION

Apricot is the third most widely cultivated stone fruit in the world, with an annual production of 3.8–3.9 million tonnes. About 80 countries produce apricot, with Turkey being the most significant producer, accounting for 15–20% of the total fruit amount (750,000 tonnes). In Europe, Italy (230,000 tonnes), France (190,000 tonnes), Spain (100,000 tonnes) and Greece (80,000 tonnes) are dominant producers (FAO, 2025), where the apricots are mainly sold as fresh fruit, while in Asian countries (Turkey, Iran, Uzbekistan, Pakistan, Armenia) apricots are mostly used as dried fruit.

Apricot production has a long tradition in Hungary. High-quality apricot fruit can be successfully marketed both domestically and internationally. However, apricot cultivation faces several challenges that make the work of farmers more difficult and threaten economic viability. Apricot is not native to the Carpathian Basin and is among the earliest flowering fruit species, as spring frost can cause considerable damage. Therefore, the proper selection of site, cultivars, and rootstocks is crucial for crop security (Szalay et al., 2021, 2024; Bakos et al., 2024). Moreover, climate change adversely affects apricot trees, as they tend to bloom earlier, and in excessively mild winters the overwintering organs cannot harden sufficiently (Guo et al., 2014; Niu et al., 2025). Another major problem is the susceptibility of cultivars to various diseases. Unfortunately, there are no resistant apricot cultivars. Fungal, bacterial and mainly phytoplasma diseases have caused significant tree death in many Hungarian orchards in recent years (Carraro et al., 1998; Bodnár et al., 2017; Galovics et al., 2024).

Hungary is located on the northern border of economic apricot production, which significantly limits the available yields and crop safety. The current volume of the production cannot cover the domestic needs, as import has a notable role in meeting market demands. The apricot production area is 5,300 hectares, while the annual yield has varied between 6,000 and 34,000 tons in the last 10 years (Fig. 1). Accordingly, harvested fruit amount shows extremely large fluctuations between years, which can be attributed to the ecological sensitivity of the plant,

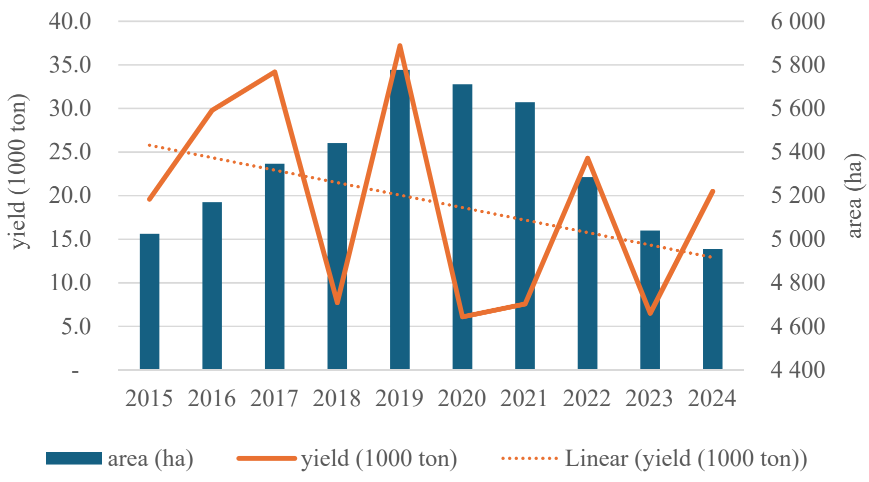

Fig. 1. Yield and production area data of apricot in Hungary (2015–2024)
Source: based on FruitVeB (2024) data own creation.

the unfavourable effects of climate change, and the high proportion of outdated technology. At the same time, geographical location of the country can also be an advantage, as Hungary is the last European apricot-producing country to harvest significant quantities in terms of harvest time, when fruits ripen in the Hungarian orchards, there is already a shortage on foreign markets. In addition, domestic apricot cultivars are famous for their excellent taste and aroma, which is a demanded product in the fresh market, and valuable raw material for the industry (Szabó et al., 2010; FruitVeB, 2024).

Apricot production technology has undergone significant development in recent decades, affecting all elements of the training systems. Over the past 50 years, more than 100 apricot rootstocks have been bred worldwide, but only 6–8 rootstocks are widely used in commercial plantations, despite the fact that the newer rootstocks have favourable properties in many respects (Mendelné Pászti et al., 2023). In the Mediterranean regions, myrobalan and wild apricot are widely used as rootstocks for apricot trees. In recent years, the myrobalan 29C plum hybrid, which is propagated by in vitro methods, has been spreading both abroad and domestic orchards (Ercisli, 2009; Miodragović et al., 2019).

The number of new apricot cultivars in the world has increased significantly in the last 20–25 years, mainly due to intensive breeding activities in the USA, France, Italy, Romania, Czech Republic and Spain (Fideghelli and Della Strada, 2010). On the fresh market, fruits with 70 g weight are required (or 40 mm diameter), but certain cultivars can reach even 80–90 g fruit weight. New apricot cultivars are characterized by at least 30–50% red skin coloration, but among the prospective cultivars there are also some whose surface coloration can be considered complete (Mellano, 2006; Roussos et al., 2011; Pallotti, 2012; Bassi and Foschi, 2020). In addition, new varieties must have adequate fruit firmness, which ensures longer storage and shelf life (Crisosto and Kader, 2004; Fideghelli and Della Strada, 2010; Elsabagh et al., 2020).

In recent decades, open canopies have become widespread in the major apricot-growing countries, among them the use of intensive compact vase is the most general in the modern plantations (Szalay et al., 2009). In the last years, in addition to intensive cultivation systems (600–750 trees/ha), more super-intensive orchards with higher planting density (1,000–1,250 trees/ha) have been planted in the apricot production, where trees are trained with one, two or more central axis (Stanica, 2019; Stanica et al., 2020; Lang, 2024; Scalisi et al., 2024). The use of two-dimensional canopies makes the manual and mechanical work more efficient, promotes robotization, and improves fruit quality. These trees form a well-lit fruit wall, where plants are characterized by the same width at the top and bottom (Musacchi et al., 2015; Long et al., 2019; Iglesias and Torrents, 2022; Neri et al., 2022). As a result of training system developments, an intensive canopy with three axis, called Chandelier or Trident, has been introduced in modern apricot orchards of Europe in recent years (Scofield et al., 2020; Pesteanu, 2021; Al Suwaid et al., 2023).

The use of frost protection devices is increasingly becoming a standard feature of modern apricot orchards. The mechanism of action, efficiency, and investment cost of different devices can differ significantly, which greatly influence the decision of producers regarding the application of individual technologies. Effective frost protection is more important in orchards where high production value can be achieved, so that frost protection technologies with high investment costs are mostly only found in super-intensive apple, cherry and apricot (possibly cherry and plum) plantations (Lakatos et al., 2011; Apáti, 2012; FruitVeB, 2024).

Among the frost protection methods, wind machines are generally considered to be one of the most effective methods. In the event of radiation frost, under optimal conditions (complete windlessness, strong temperature inversion), they can raise the temperature of the plantation by 3–4 °C, thus providing protection even in the most sensitive phenological phases up to a chilling temperature of about −4, −6 °C (Snyder and Melo-Abreu, 2005; Heusinkveld et al., 2020; Dai, 2023). Another effective frost protection solution is plantation heating, whereby the energy loss during frost is compensated by burning fuel. In Hungarian intensive apricot orchards the paraffin candle method is the most common. The heat generated by burning candles can raise the temperature of the plantation by 5–7 °C, but at the same time it is expensive and requires a high degree of organisation (Lakatos et al., 2012; Balawejder et al., 2024).

Based on the above mentioned, competitive apricot production can be achieved by planting modern orchards with frost protection systems, maintained with modern expertise. However, different technologies can result different level of yield security and yield, as well as the farm economics indicators of individual technologies also differ. In this paper we aimed to analyse the costs, income and investment-efficiency of high quality, well-managed apricot plantations with various intensity level.

MATERIALS AND METHODS

Deterministic simulation models were used for model-building, which essentially derive economic indicators not from analytical records and accounting data, but from technological parameters, i.e. they take real processes as a basis and assign unit prices to the assessed natural inputs and derive the financial processes. Furthermore, sensitivity analyses were used to illustrate the potential impact of individual factors on the most important economic indicators. The following analytical methods were used for the operational economic evaluation: cost-benefit analysis, investment-economic analysis, and sensitivity tests. Within the sensitivity tests scenario analyses were performed on the factors that have the greatest impact on production efficiency and economic efficiency.

The used cost-benefit analysis is based on a methodology developed and subsequently refined at the Debrecen School of Operations Management. Cost-benefit analysis has been used in many areas of agribusiness to evaluate the cost-income rates of individual sectors. These agriculture-related analysis include the following publications: for milk production by Hingyi (2002), for the poultry sector by Szőllősi (2008), in the beef cattle sector by Szabó (2009), in the sheep sector by Cehla (2011), in the tobacco sector by Bittner (2011), and by the Agricultural Economics Research Institute on the cost-income analysis of major agricultural products (Béládi-Kertész, 2013). Cost-benefit analysis is regularly applied in scientific research on fruit production (Jalic et al., 2022; Vasuki and Soundariyan 2022; Ravalomanana, 2023). Economic analysis of investment was performed (Castle et al., 1992; Szőllősi and Szűcs, 2013; Brealey and Myers, 2005; based on the works of Nábrádi and Szőllősi, 2007) to provide a comprehensive economic assessment of the entire life cycle of the plantation, like by Apáti (2007) and Szabó (2016) for apple orchards. Further economic investment-analyses have been conducted specifically focusing on fruit orchards for a number of species by Sojková and Adamicková (2011); Badiu et al. (2015); Singh and Nandi (2020); Akcay and Uzunöz (2005). Economic and investment profitability analyses, focusing on the whole entire plantation life-cycle in apricot sector, are the focus of research in the major apricot-producing countries: Ucar and Engendeniz (2021); Lakdan (2018); Paksoy and Aslan (2020). However, these analyses cannot be directly compared with our analysis, as they cannot be brought onto a common platform due to differences in regional conditions, cultivars used, just as the effects of climate and yearly weather conditions.

The analysis is based on the collection–at commercial farms–and compilation of the natural inputs of the entire production technology by breaking down each work operation into its basic operation movements and determining its material, labour, and machinery costs. Natural input costs collected from the 12 producing companies have been converted into costs at input market prices:

- Price lists of the four leading domestic trading companies were used to determine the price of input materials;
- Machinery costs were derived from the calculations based on 40 producing farms and machine rental rates;
- While for labour, relative wage costs based on current wage conditions were applied in the calculations.

For the revenue analysis realized yields and sales prices were obtained from the producing farms, and additionally data on sales prices was collected from trading companies, three producer organizations and numerous secondary sources. Data collection from producing farms was based on personal visits and professional consultation.

In order to accurately understand the results of economic analyses, it is inevitable to define the main conditions that set the framework for interpreting the data. Therefore, we have consistently sought to use the same methodology for each production method, filtering out random differences and distorting effects that arise from differences in the size, production structure, equipment, etc. of the data-providing enterprises, and which are not related to the sector or production method in question. The aim was not to analyse the reporting companies, but to have a comprehensive review of the sector. The parameters of the plantations included are detailed in Table 1.

Semi-intensive plantations with compact vase canopy are typically planted with around 666 trees per hectare. These orchards are irrigated, consist of several cultivars–among others, but not limited to: 'Pricia', 'Nirosa 2', 'Rubista', 'Lido', 'Bergeval', 'Orange Rubis', 'Flavor Cot', 'Kioto', 'Rubely', 'Alissa', 'Faralia'–, produce yields of 13–18 t/ha on a long-term average, with 80% rate for fresh market, which requires manual harvesting. The calculations are referred to hand-picked, post-harvest sorted, pre-cooled, 10 kg crates of first-class products.

Super-intensive plantations are typically planted with a trident canopy, with around 1,250 trees/ha, equipped with irrigation and a support system which is suitable to apply a hail net with both longitudinal and transverse anchorage. Under ideal weather conditions, these plantations can produce a yield of 35–40 t/ha which is the level of Italian plantations, with an extremely high rate over 95% for fresh market.

Table 2 shows the results of the analysis for the period until full bearing. Semi-intensive plantations with a compact vase canopy structure usually start bearing within four years after planting. The income generated during the first four years of the plantation's life cycle approximately cover maintenance costs. No significant income can be expected in the first two years, but after the third year, due to rapidly increasing yields (2.9 and 5.9 t/ha in the third and fourth year respectively), the income is already sufficient to cover the annual maintenance costs. Thus, a net investment cost of EUR 9,200/ha can be applied in the calculations, which will result in an amortization cost of EUR 615/ha in fully-bearing years. Super-intensive plantations

Table 1. Main parameters of the apricot plantations analysed

Definition	Super-intensive with frost-protection	Super-intensive	Semi-intensive
Rootstock	myrobalan (*Prunus cerasifera*)	myrobalan (*Prunus cerasifera*)	myrobalan (*Prunus cerasifera*)
Age of the plantation	fully bearing	fully bearing	>15-years
Canopy	trident	trident	vase
Tree height	4 m	4 m	3 m
Row distance (m)	4–5	4–5	5
Spacing (m)	1.5–2	1.5–2	3
Hail net	equipped	equipped	partially
Frost protection	equipped	not available	not available
Rate of fruits for fresh consumption/ processing	100:0	100:0	80:20
Main technological parameters of the plantation			
Yield (t/ha)	26.0	18.8	7.8
- from which for fresh consumption (%)	90%	90%	80%
- from which for industrial processing (%)	10%	10%	20%
average selling price (EUR/kg)–fresh consumption	1.40	1.33	1.28
average selling price (EUR/kg)–industrial processing	0.84	0.82	0.81

Source: based on calculations from own data-collection.

Table 2. Investment costs of the analysed apricot plantations (EUR/ha)

Cultivation system	Super-intensive with frost protection	Super-intensive	Semi-intensive
Total planting cost	**71499.48**	**51776.38**	**10832.23**
Maintenance costs until full-bearing	18664.79	18668.60	11671.66
Length of the pre-bearing period	*3 years*	*3 years*	*4 years*
Total investment cost	**90164.27**	**70445.14**	**22504.12**
Income during the pre-bearing season	26251,58	24974,35	13291,64
Net investment cost	**63912.69**	**45470.79**	**9212.48**
Expected life-cycle of the plantation (from planting)	*16 years*	*16 years*	*19 years*
Useful life of the plantation (from bearing)	*13 years*	*13 years*	*15 years*
Yearly amortisation cost in bearing ears	***4916.36***	***3497.75***	***614.17***

Source: based on calculations from own data-collection.

can reach their maximum yield already within 3 years, producing 3.5 kg/tree already in the second, while 11 kg/tree in the third year, and maximum yield can be expected from the 4th year onwards. Due to the rapid bearing, net investment cost is calculated at a level of EUR 6,500–7,800/ha, which is lower than the planting cost. Therefore, for a life cycle of 13 bearing years (calculated from the start of bearing), an amortisation of EUR 3,400/ha can be calculated for super-intensive plantations without frost protection and almost EUR 3,970/ha for super-intensive plantations with frost protection.

Direct, normative subsidies available in fruit sectors were taken into account as per the following:

1. Basic Income Support Scheme (BISS): €147/ha
2. Complementary (redistributive) subsidy (CRISS): €40/ha
3. Agri-environmental program (AEP): €80/ha

CRISS can be applied at a rate of €80/ha for territories smaller thank 10 hectares, with the first 10 ha, at €40/ha for the total production area between 11 and 150 ha, and not applicable for the rest of the area over 150 ha. On average, we calculated €40/ha support for all crops. Participation in the AEP is not mandatory, but as it applied for by the majority of the producers, it has been included it in our calculations.

4. Coupled Income Support (CIS):

Extensive fruit production: €167/ha (€143.54 and €191.39/ha)

Intensive fruit production: €355/ha (€280.11 and €429.50/ha)

Each production-linked subsidy may vary within the indicated range, thus the midpoint of the range was used in our calculations.

In our calculations, a cost structure based on both work operations and expenditure types has been used. In order to provide an exact interpretation it is important to note that in this calculation, labour and machine costs were taken into account as per the following:

- The cost of labour only includes the total wage costs of actual manual labour. Human labour related to the operation of machinery and buildings (e.g., machine operator wages) is not included.
- Machinery costs are a complex cost category and include all fixed and variable material, labour, amortisation, and other costs associated with the operation, maintenance, and repair of the machinery in question.

Determining profitability can be relative, so the accepted method in business economics is to compare the profit of our investment to the return on some other, alternative financial investment. Specifically, it is compared to an alternative investment, the profit of which can be calculated precisely and which is risk-free, because it is only possible to evaluate the economic efficiency of our activities in relation to a fix benchmark.

Such alternative investment option could simply be a bank deposit, which currently offers interest rates of between 3 and 6%. Though Szűcs and Szőllősi (2008) recommend to take the dividend on government bonds and treasury bills into account when determining the calculative interest rate, however, as they are "almost completely" risk-free investments, government sovereign debts are even more suitable for this purpose, especially since they can be long-term investments with maturities of 10–15 years, similar to the lifespan of a plantation (in the current calculation the interest rate for them was set at 6.5%).

Dynamic investment-efficiency indicators provide more accurate economic results. Our analysis was based on four dynamic indicators, as they take into account the time value of money, thus enabling us to make economically valid decisions (Horváth, 1997; Pfau, 1998; Szőllősi, 2008):

- Net Present Value (NPV)
- Profitability Index (PI)
- Discounted Payback Period (DPP)
- Internal Rate Return (IRR)

Based on the recommendation of Nábrádi and Szőllősi (2007), the uncertainty arising from changes in the natural and – both external and internal – economic environment must be addressed with sensitivity analyses. It is therefore advisable to determine the impact of these changes on the results, which explains the fact that a sensitivity analysis was performed on the results of the present calculation.

RESULTS

Productive period

Investment, production costs. The costs of semi-intensive apricot cultivation (Table 3) are determined by the need for regular annual pruning (the professionalism of pruning has a major

Table 3. Apricot production costs divided as per technological element in an average production year *(EUR/ha)*

Technological element	Super-intensive with frost-protection Yield: 26.0 t/ha	Super-intensive Yield: 18.8 t/ha	Semi-intensive Yield: 7.8 t/ha
Pruning	1074.47	1074.47	636.88
Soil and row cultivation	264.53	264.53	160.50
Nutrient-management	861.33	861.33	470.12
Plant-protection	1029.54	1029.54	974.76
Yield management	897.34	897.34	448.67
Irrigation	616.56	616.56	576.38
Other operations	4590.75	714.72	421.00
Production technology expenditures total	***9334.52***	***5458.48***	***3688.33***
Harvest	3131.13	2323.52	1307.88
Postharvest costs	2434.69	1785.79	771.16
Amortisation of the plantation	*4916.36*	*3497.75*	*614.17*
Direct cost of production	**19816.70**	**13065.55**	**6381.54**
from which: operating costs	*13018.71*	*8835.60*	*5121.04*

Source: based on calculations from own data-collection.

impact on yield), as well as 10–14 plant protection sprays, 2 chemical weed control treatments and continuous row maintenance. Depending on the given crop-year these plantations typically require an average of 600 m^3/ha of water irrigated. However, a specific technology element is manual thinning (chemical thinning similar to that used for apples is not available), which plays a key role in achieving the adequate fruit size, as the fruit remains small in the case of a high crop-load (size 35 mm+ is considered as Class I, but higher prices can be achieved with apricots of size 40 mm+). The labour input for thinning takes a quarter to half of the time required for harvest, i.e., depending on the fruit set, 50–150 h/ha. The category "Other operations" includes replacing missing trees, removing root and stem suckers, and other plantation maintenance works. In contrast to previous methods tree mortality rate in the present calculation was set to be only 2%, as experience has shown that planting certified virus-free, mature, homogeneous planting material obtained from reliable sources during the investment period can minimize the infections associated with tree mortality – usually phytoplasma, possibly fungal or bacterial diseases.

The annual production costs of semi-intensive apricot cultivation systems (pruning, soil and row cultivation, nutrient management, plant protection, irrigation, manual thinning, replanting of missing trees, other operations) are calculated around EUR 3,600 per hectare. It is important to note that this amount is largely a fixed cost, which does not vary significantly depending on the annual yield, since even with a very good yield of 15–20 t/ha or a third of this yield, it is not possible to reduce the basic technological expenditures. In the case of a lower yield the production cost can be reduced by EUR 250–650 (e.g. the cost of fruit thinning), on the contrary, in case of a higher yield the production cost does not increase to a significant extent (Table 3).

In super-intensive plantations with an average density of 1,250 trees/ha and a trident canopy, cultivation costs differ significantly from those of semi-intensive plantations due to differences in the cultivation system. These plantations are characterized by professional nutrient management (use of solid fertilizers, foliar fertilizers and fertigation) continuously supervised by a technical consultant, reasonable plant protection management (12–16 times/year), efficient and economical use of pesticides, protection against hail, and machine pruning. Fruit thinning is a labour-intensive operation, requiring up to 300–350 working hours/ha in an extremely good year. In our calculations, we estimated an average of 200 working hours/ha. In super-intensive plantations, an average of 800 m^3/ha of water is irrigated, but depending on the crop-year, producers apply the amount necessary to meet the needs of the trees. The rate of tree replacement was determined to be low, at 1% (Table 3).

In the case of super-intensive plantations, cultivation costs are 50% higher than in semi-intensive cultivation systems, i.e. EUR 5,450/ha (Table 3). It is recommended not to reduce in any year in order to maintain good conditions. The usage frequency for the frost protection system was set average three times a year, which assumes that there will be years when it will need to be used six times and years when it will not be used at all. In a super-intensive plantation equipped with frost protection an additional cultivation technology cost of EUR 3,600/ha occurs, which includes the depreciation of the frost protection system, just as the material and labour costs of its operation.

In addition to cultivation costs, plantation amortisation is definitely considered as a fixed cost, while harvesting cost apply to a variable extent depending on the approximate yield. The apricot picking performance – depending on yield, fruit size, work organization, canopy shape, etc. – ranges around 30–40 kg/person/hour (240–320 kg/person/day). In the present calculation 31.5 kg/person/hour was considered for the compact vase canopy shape and 40 kg/person/hour for the trident canopy, as the latter production system can enable more efficient picking performance. Summarizing, it can be concluded that the manual labour requirement in a super-intensive plantation with frost protection is twice as high (1,240 working hours/ha) as in a semi-intensive cultivation system (584 working hours/ha), while in super-intensive plantations without frost protection, 1,006 working hours are required per hectare in an average growing year. However, it is important to note that the labour requirement per ton of yield varies inversely: the specific labour demand of the most modern cultivation systems is only two-third of the labour requirement of semi-intensive plantations.

Sold product was defined as assorted, pre-cooled fruits packaged in 10 kg boxes, so additional post-harvest costs occur–beside direct costs – such as EUR 0.08/kg for sorting and EUR 0.01/kg for cooling (calculated with 1–3 days of cooling). Based on this, for the semi-intensive cultivation system direct costs are calculated at a level of EUR 6,380/ha, twice as much in the case of the super-intensive system, and three times as much in the case of the super-intensive plantation with frost protection (Table 3).

In an average crop-year, the cost price per kilogram of apricots produced proved to be the highest in a semi-intensive cultivation system with EUR 0.81, while the lowest in a super-intensive plantation without frost protection (EUR 0.70/kg) and EUR 0.76/kg in a super-intensive plantation with frost protection. It is important to note that we do not differentiate between the industrial and fresh market shares of the crop in terms of cost price, even though there is approximately a twofold difference in their market value, and fresh market apricots are considered to be the main product and industrial apricots to be a by-product. The reason for this is that it is not possible to separate the costs of the industrial and fresh market shares, because they are generated on the same tree, using the same technology, i.e. within the same system. The result of this approach is that the industrial portion generally realizes a loss, while the fresh market product carries the potential for profit, which is related to the economic constraint that we must produce the largest possible fresh market rate in order to achieve acceptable profitability.

The lower the crop security level, the wider the range of variation in production costs is in the different years. Since, in order to ensure good tree condition, practically all costs (pruning, nutrient management, soil and row cultivation, irrigation, plant protection, depreciation costs) are incurred each year in addition to fruit thinning, other operations (frost and hail protection) and harvesting, thus the rate of fixed costs is rather high. In terms of production costs the amount of the yield is of great importance on which the costs are divided. The lowest variation in production costs along the years can be found in super-intensive plantations with frost protection, while production costs vary on a wider scale in semi-intensive plantations, because yields here fluctuate over the widest range.

Yield, revenue

In the decade between 2015 and 2024, domestic apricot production showed a downward trend (Fig. 1), which can be attributed to the following reasons:

- On the one hand, due to its early flowering season (first half of March, beginning of April), apricot is highly exposed to the risk of spring frosts,

- Furthermore, it is very sensitive to weather conditions during and immediately after flowering (bees do not fly in windy weather, pollination is poor; in cloudy, cool weather fertilization and initial cell division are poor, which adversely affects fruit size later on),
- In addition, in the case of sensitive cultivars, 5–10% of the trees may die each year, in extreme cases, 10–20% of the trees may die within a single year, further reducing the achievable yield.

Climate change has caused a significant decline in crop security for apricots, especially in case of plantations that are not effectively protected against frost. Therefore, according to our estimates, the national harvest will develop as follows over the next five years (Table 4): once every five years, the sector will be able to produce 100% of the national yield amount (in this case, the national harvest is expected to be between 25,000 and 30,000 tons), while in two years significant frost damage can be expected, with a national harvest level of around 25% (6–8 thousand tons), and in two years moderate frost damage is supposed to occur, with the national harvest amounting to around 50–60%. In other words, considering a five-year average, the national harvest is expected to be around 12,500–15,000 tons, which is slightly over the half of the national 100% harvested amount. In the present calculations, the least modern, semi-intensive plantations will only achieve the national average yield (52%), as they are not equipped with protection against hail or frost (but this yield level is still significantly above the national average, as these plantations are cultivated on a high technological level. Super-intensive plantations have higher yields due to crop protection technologies involved, while their theoretical maximum yield is also much higher.

The yield that the analysed production systems can achieve at the farm level compared to the estimated national yields has also been determined. In our opinion, in the absence of frost protection, semi-intensive cultivation systems are capable of achieving the national yield level at the farm level as well. However, a significant difference is that they produce a much higher average yield (7.8 t/ha) than the average domestic semi-intensive or extensive plantations (national average of 3.6 t/ha over 10 years, 2.6 t/ha over 5 years). In addition to the above-mentioned parameters, super-intensive plantations are characterized by their high cost price, which means that, in addition to the extremely high level of expertise and high input costs involved in cultivation, the selection of a suitable production site is of particular importance (above 200 m ASL, hillside location), as this factor alone provides effective protection against frost. Therefore, due to good tree condition, appropriate site selection, and the selection of good cultivars, super-intensive plantations can achieve yields that are 10 percentage points higher than the national average at the farm level. In addition to the above parameters, if super-intensive plantations are also equipped with effective frost protection, crop security can be

Table 4. Relative yield levels achievable in the different production systems

National yield amount	Super-intensive with frost-protection	Super-intensive	Semi-intensive
1st year: 100%	100%	100%	100%
2nd year: 60%	100%	80%	60%
3rd year: 50%	95%	75%	50%
4th year: 25%	70%	50%	25%
5th year: 25%	60%	30%	25%
5-year average: 52%	**85%**	**62%**	**52%**

Source: based on calculations from own data-collection.

further enhanced and yields 33 percentage points higher than the national average can be achieved at the farm level. In super-intensive plantations, the achievable yield level is 62% (18.8 t/ha) of the maximum achievable yield level, while in super-intensive plantations with effective frost protection, up to 85–90% of the maximum producible yield can realistically be achieved on a 5-year average, which means 26.0 t/ha. In terms of quality, super-intensive plantations achieve a minimum of 90% fresh-market yield rate, while semi-intensive plantations achieve at least 80% edible yield on average over years.

Sales prices for apricots have been fairly stable in the period before the recent years: the fruit has generally been easy to sell at a good price. However, in recent years, the oppressive effect of increased European production unfolded its effects. The first such year was 2014, when very high yields were achieved at both European and domestic levels, causing prices to fall by an average of 15–20% (which was unusual for apricots at the time) and part of the crop to be unsaleable. In the last 5–6 years, favourable sales prices could be achieved in years affected by frost damage (net producer price of EUR 1.55–1.85/kg for 1st class, fresh-market apricots of size 40–50), while in good years, net producer prices typically range from 0.75 to 0.90 EUR/kg.

The price of industrial apricots typically ranges between EUR 0.70 and EUR 0.90 per kilogram (mainly purchased as raw material by industries producing apricot pulp, juice, and higher value-added processed products, such as the brandy and refrigeration industries). The price of apricots on the fresh market depends on the size of the fruit, but in recent years it has been much more dependent on the market situation. Apricots supply a perfect example of the basic economic principles of market equilibrium:

- In the event of a low harvested yield amount, demand for apricots exceeds supply, resulting in high producer prices (EUR 1.57–1.83/kg).
- In case of a good harvested yield amount, a supply market develops, in which case prices of EUR 0.75–0.90/kg characterize the food market.
- In the event of a partial harvest (50–60% of the national harvested amount), market prices are around EUR 1.3–1.45/kg.

Based on sales revenue, yields, quality and sales prices, semi-intensive apricot orchards can generate EUR 9,245 per hectare, while super-intensive orchards can generate 2.5 fold this amount and super-intensive orchards with frost protection can generate almost four times higher amount (Table 5). All production systems involved in the analysis receive subsidies

Table 5. Outputs and income of the analysed apricot production systems in an average crop-year

Category	Unit	Super-intensive with frost-protection	Super-intensive	Semi-intensive
Yield amount	t/ha	26.0	18.8	7.8
from which: fresh-market	t/ha	90%	90%	80%
industrial processed	t/ha	10%	10%	20%
Average sales price: fresh-market	EUR/kg	1.40	1.33	1.28
industrial processed	EUR/kg	0.84	0.82	0.81
TOTAL REVENUE	EUR/ha	34980.70	23968.94	9244.51
Indirect subsidies	EUR/ha	622.00	622.00	622.00
TOTAL INCOME	EUR/ha	35602.70	24590.94	9866.51

Source: based on calculations from own data-collection.

linked to intensive production, so the total revenue is of the same order of magnitude as the sales revenue.

Results and efficiency of management

Based on the yield, price, and cost ratios presented so far, Table 6 summarizes the main indicators expressing the income-generating capacity and efficiency of apricot production in each cultivation system.

With average yields of around 7.8 t/ha and the average sales prices outlined above, semi-intensive apricot plantations can achieve a break-even amount of around EUR 3,500 per hectare, with a direct cost-proportional profitability of 55%, which are considered as good and acceptable parameters. Super-intensive plantations can generate a break-even amount of EUR 11,800, while due to the high depreciation ratio, EBITDA of EUR 15,750 per hectare can be expected, with an outstanding direct cost-to-income ratio of 88.2%. Super-intensive plantations with frost protection achieve even higher EBITDA, as the amortisation costs on invested assets are even higher here and they can generate a break-even amount of EUR 15,780 per hectare.

On the basis of the above mentioned, it can be concluded that even less modern, semi-intensive apricot orchards can generate acceptable income and profitability when production standards are high (intensive cultivation). However, orchards with much higher capital requirements, equipped with (either in part or in whole) crop protection technologies, have a much higher income-generating capacity and, in addition, the product can be produced at a lower cost, despite the much higher production costs per hectare.

The economic efficiency of the investment over the entire lifetime of the plantation

Investment-profitability calculations show that, under current market conditions, apricot production is profitable in all three analysed cultivation systems, even under the current weather and market conditions (Table 7). Even in the case of plantation establishment financed entirely

Table 6. Profitability and efficiency of apricot production in an average crop-year

Category	Unit	Super-intensive with frost-protection	Super-intensive	Semi-intensive
TOTAL INCOME	EUR/ha	35602.70	24590.94	9866.51
Total indirect costs	EUR/ha	19816.70	12785.90	6331.40
Operation costs	EUR/ha	13018.71	8835.60	5121.04
BREAK-EVEN AMOUNT	EUR/ha	15786.00	11805.04	3535.11
EBITDA	EUR/ha	22583.99	15755.34	4745.48
Direct costs	EUR/kg	0.76	0.68	0.81
EBITDA margin	%	173.47%	178.32%	92.67%
Direct cost-proportional profitability	%	79.7%	92.3%	55.8%
Income-proportional profitability	%	44.3%	48.0%	35.8%
Income level (revenue-proportional profitability)	%	44.3%	48.0%	35.8%
Cost level	%	55.7%	52.0%	64.2%

Source: based on calculations from own data-collection.

Table 7. Economic indicators of the investment in case of the analysed apricot production systems ($r = 6.5\%$)

Category	Unit	Super-intensive with frost-protection	Super-intensive	Semi-intensive
Planting costs	EUR/ha	71499.48	51776.38	10832.46
Net investment cost	EUR/ha	63912.69	41835.31	8460.48
Useful life cycle	year	13	13	15
Amortisation cost	EUR/ha	4916.36	3218.10	564.03
NPV	EUR/ha	93863.58	67050.66	25462.29
IRR	%	17.83%	18.07%	20.60%
DPP	year	8.	8.	8.
PI	–	2.31	2.30	3.35

Source: based on calculations from own data-collection.

from own resources, all three plantation types examined return in 7–8 years, with an internal rate of return (IRR) of 17–21% at the end of the plantation's life, which is a completely realistic return on investment for a fruit plantation.

However, there is a huge difference between the various cultivation systems in terms of the net present value (NPV) that can be realized at the end of the plantation's life cycle. This indicator expresses how much more profit our plantation generates over its entire life cycle than if the inputs would have been invested a bank at 6.5% interest for a term equal to the lifespan of the plantation rather than establishing a plantation. Based on the results, we could achieve the same results as with plantation establishment by investing our initial capital in a bank deposit with an interest rate of around 17–21%. At the end of its useful life, the semi-intensive plantation generates an NPV of almost EUR 25,400 per hectare, the super-intensive plantation 2.5 times that, and the super-intensive plantation with frost protection 3.6 times that (incidentally, already by the end of the 16th year).

Investment subsidies significantly improve economic indicators, especially parameters reflecting capital adequacy (IRR, PI), but the payback period is also shortened to the second and third years after the start of bearing (Table 8). On average, investment subsidies of 60% can currently be calculated for the plantation and its complementary infrastructure (hail nets, frost protection). If this level is even higher, requiring even less own contribution, the investment-economic indicators will improve further.

Table 8. Economic indicators of the investment in case of the analysed apricot production systems under 60% subsidy rate ($r = 6.5\%$)

Category	Super-intensive with frost-protection	Super-intensive	Semi-intensive
NPV (EUR/ha)	136763.26	94960.15	31961.77
IRR (%)	34.13	33.35	34.12
DPP (year)	5.	5.	5.
PI	5.78	5.59	8.38

Source: based on calculations from own data-collection.

CONCLUSIONS

The main objective of this study was to evaluate the cost ratios, the income-generating ability and the efficiency of the various apricot production technologies.

The semi-intensive apricot orchard, with an average yield of approximately 7.8 t/ha and the average market prices outlined above, can generate a gross margin of around EUR 3,500 per hectare, corresponding to a direct cost profitability ratio of 55%. These parameters can be considered satisfactory and economically acceptable. In contrast, super-intensive orchards achieve a gross margin of EUR 11,800, and due to the higher depreciation rate, they can also realize an EBITDA of EUR 15,750 per hectare, accompanied by an outstanding direct cost profitability ratio of 88.2%. Super-intensive orchards equipped with frost protection attain an even higher EBITDA, since the depreciation costs of the invested assets are further increased, while still being able to realize a gross margin of EUR 15,780/ha. According to the results of the investment analysis, by the end of their economic lifespan, semi-intensive orchards generate an NPV of nearly EUR 25,400 per hectare, whereas super-intensive orchards achieve 2.5 times this value, and super-intensive orchards with frost protection reach 3.6 times this amount.

Based on calculations, it can be stated that despite the unfavourable weather conditions, domestic apricot cultivation is a profitable and economical activity regardless of the cultivation system, if the level of cultivation is high, but the use of modern, frost-protected plantations and technologies results in significant differences in costs and income. Therefore, the key to the long-term economic success is the high willingness to invest, the application of modern technology, the selection of suitable growing sites and cultivars, and the conscious protection against spring frosts.

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