University of Debrecen

Kerpely Kálmány Doctoral School of Crop Production and Horticultural Sciences

Head of the Doctoral School:
Prof. Dr. Nagy János
D.Sc.

Supervisor:
Prof. Dr. Nagy János
D.Sc.

Doctoral (Ph.D.) dissertation abstract

THE IMPACTS OF THE INCREASE OF PRODUCTION INTENSITY AND TECHNICAL DEVELOPMENTS ON THE EFFICIENCY OF APPLE PRODUCTION

Prepared by:

Szabó Viktor
Ph.D. candidate

Debrecen
2016

1. Backgrounds and objectives of the doctoral dissertation

In recent years (2010-2014.) the production of the Hungarian horticultural sector fluctuated between 290-320 billion HUF per year, i.e. 25-35% share in the crop and horticultural products and 14-16% share in the entire agricultural sector. The vegetables usually have an output of 100-130 billion HUF, the fruits about 80-120 billion HUF, which is together 2/3 of the total output of the Hungarian horticulture sector and 10-12% of the total agricultural production. However, its around 20% share in the agricultural exports enhances the importance of fruit and vegetable sector. Additionally, it plays an even more important role in the employment, since due to the nature of its work operations, the unit labour demand of fruit production can get above many times the unit labour demand of arable crop sectors.

Apple production is a significant factor in the Hungarian fruit sector, which is in a rather difficult situation regarding to the competitiveness. The Hungarian apple orchards are not advanced enough, in spite of significant grubbing-ups, a quarter/third of orchards is still too old. Based on the statistical data of censes on orchards, grubbing-ups affected mostly the aged, more than 25-30 years old orchards, which were supposed to be able to achieve low yields and low dessert quality proportion, cultivated extensively with low input levels and without irrigation. 60-80% of the apples produced in Hungary is still being processed by the food industry ensuring meagre income to the majority of the producers due to the low prices of apples for industrial purpose, the low yields and quality of the aged orchards. Domestic fruit production sites have been constantly decreasing; instead of the 41000 hectares at the millennium nowadays are merely 26000 hectares apple orchards in Hungary. Due to the extremely heterogeneous quality and poor crop safety of the orchards, the annual yield varies between 300 and 900 thousand tons, and the profitability is critical for a significant part of apple producing businesses.

In my opinion, the increase of the income-generating capacity and efficiency of apple production could be achieved by increasing the orchard intensity on the one hand, as this could increase yields, enhance quality and reduce unit costs. On the other hand, there is a need to enhance the quality of postharvest processes, making possible prolonged sales and the production of quality and quantity meeting consumers' expectations, moreover, significantly improved average selling prices.

The intensity of an orchard is a complex concept. At present, the most intensive apple orchards in Hungary have a tree density of 2500-3000 trees/ha (3.3-4.0 x 1.0 m spacing), a conventional support system and drop irrigation. Only in rare cases are hail protection net systems or frost protection systems installed in the orchards. The typical planting material is summer grafted one year old tree, that does not provide substantial yields for two years after planting, and attain its full starting to bear (reaching the maximum yields) is expected in about 6 years. In my view, the increase the orchard intensity involves any additional capital investment making possible higher specific yields, better quality and enhanced crop safety, more quickly starting to bear, as well as improved work efficiency. Important elements of this process are: a support system with 3.5-4.0 m height suitable for holding hail protection nets, a hail protection net system, Knipp tree as planting material and a work platform significantly increasing the work efficiency. Higher support system and hail protection nets significantly contribute to the increase of yields and quality and enhance of crop safety. The use of Knip trees enables reaching the maximum yields about 2 years earlier, while work platforms ensure efficient work operations during harvest and thinning of the crop.

In recent years, a growing number of super intensive apple orchards have been established with these elements, which have been dominant in Italy, Austria and Germany for around fifteen years. However, the question, whether these capital intensive investments under Hungarian circumstances can return, arises after. The significance of the postharvest phase - where the product gets its final form meeting consumer and customer expectations - has been displaying a strongly growing tendency in Hungary as well, similar to the most advanced European apple producing countries, and its further increase is expected. So, the harvested apples are not the final product in the apple producing process, but they have to be capable of being processed to a great-looking final product meeting customer expectations. The final product is prepared during the postharvest processes (storage, sorting, and packing).

Therefore, the present Ph.D. thesis focuses on the technological an economic impact of these development and modernisation opportunities. In addition to the signification of the above mentioned professional horticultural and economic factors, the theme selection is justified by the fact, that these specific areas of the economics of apple production have not been substantially discussed in the Hungarian body of literature yet, so the results of the analysis fill gaps and ensure the novelty of results and conclusions.

Considering the above described currently very actual and pending issues of apple production, *the main objective of* this Ph.D. dissertation is to give science-based answers to the following questions:

- Is it worth under Hungarian ecological and economic conditions introducing super intensive apple orchards with high tree density (>3000 tree/ha), hail protection net system and Knipp-trees compared to intensive apple orchards (2500 tree/ha tree density, summer grafted one year old trees as planting material, conventional support system without hail protection net)?
- How and what extent can influence the presence of postharvest technology and infrastructure (cold storage, grading and packing machines) the economics and investment efficiency of apple production?
- Which operating model, which combination of cultivation and postharvest results in the most efficient production?

In connection and adjustment to the main objectives, the *hypotheses* of this work are the next ones:

- The introduction of super intensive apple orchards can be considered even under Hungarian ecological and economic circumstances as an efficient investment.
- The presence of postharvest technology significantly improves the profitability of production.
- The highest level of postharvest supply, i.e. the co-existence of production, storage, sorting, grading and packaging processes, results in the most favourable investment analysis indicators.

Achieving these objectives makes possible the economic judgement on orchard intensity enhancing elements and super intensive orchards, the measurement of the profitability effects of the postharvest technological level, the choose of the most effective operating model, furthermore the determination of the business management benefits and disadvantages of the major operating models.

The players of the Hungarian apple industry are extremely heterogeneous regarding to the farm size, the productivity, the technological level, the expertise and the capital strength. Therefore, the analyses in this research were narrowed down to the modern orchards producing on good production level. Thus, the results and conclusions concern these orchards, rather than the national average.

2. Materials and methods

The *analysis methodology* used for achieving the objectives was the methodological tools of cost-benefit analysis, the investment analysis and the sensitivity analysis of their results. This thesis includes classic business management analyses based on the methods developed and taught in the Agronomy School of Debrecen.

The central element of *data processing* is the simulation modelling based mostly on the primary *data collection* in apple producing businesses, focusing on the natural inputs and yields, and partly on secondary data collection. To perform the tests, a deterministic simulation model was created with input data of technological factors on the one hand, and economic parameters on the other hand. This model was suitable for the complex cost-benefit analysis of apple production, the investment analysis and the sensitivity studies, whereby the impact of changes in input and output prices, yields, investment and maintenance costs and supports on economic result an profitability could be evaluated. The basic unit of the analysis was not a business but a one-hectare unit technology, i.e. inputs and outputs related to the apple production of the business projected to 1 hectare orchard surface.

The following pieces of information were to be collected for the analysis and data processing activities, i.e. the business management evaluation of the whole apple production:

- in the production phase realized yields and product quality and production costs (input prices and expenses),
- in the postharvest phase the costs of storage and preparation (sorting, packaging), storage losses, and the characteristics of the goods made by this process,
- in the marketing phase the realised selling price.

In addition to the above mentioned the investment costs of orchards, storage, sorting and packing capacities (i.e. the initial invested capital demand of the production) were needed to determine in order to perform the investment analysis.

During the development of the data collection and analysis method of the research, the so called "mosaic principle" (according to *Apáti, 2007*) was an important principle as well. The "mosaic principle" means that one or some different conditions of the reality are aimed to be simulated, so it is not absolutely necessary to collect data in every farms on every single operation, moreover, the pieces of information related to the different production phases can have different sources, and data on a particular phase can be obtained from multiple sources. The point therefore is not from which source exactly the data of one phase comes from, but it is essential to have some reliable data on every main condition of every phase. Thus, any condition of the production, the postharvest and the marketing (market) can be "tiled", combined optionally.

During the data collection - based on the methods of the Agronomy School of Debrecen - the large amount of data was the production costs of the orchards. The calculation of the costs needed the collection of expenditures of production technology (physical indicators) and input prices (price of materials, unit costs of machine operations, labour costs). Expenses incurred in connection with some apple cultivation operations were collected from businesses producing apple in modern orchards. The prices of input materials were collected from the distribution companies, the costs of machine operations were able to be calculated based on the tariffs of machine work services. The price of labour, i.e. wages and taxes both for permanent and casual employment were calculated on the basis of common wages in agricultural enterprises and the applicable laws. Average wages of temporary employment are 600-800 HUF/working hours, while in case of permanent employment the wages are about 1500-2000 HUF/hours.

Data on the yield and quality also come from the apple-producing businesses. Collection of sales prices was possible in the same place and in the Havita PSC.

Natural inputs were collected for the cultivation works, for postharvest operations, this encountered partly difficulties, and therefore in respect of these, “ready” cost data - mainly collected from the cold store and sorting and packaging plant operated by Havita PSC - was used as data source.

Data on investment costs of orchards and postharvest infrastructure were collected from apple producing businesses and PSC-s implementing similar investments recently.

The calculations presumed an intensive apple orchard in good condition being cultivated on high level; moreover, good production level and high technological standard of discipline were assumed as well. The calculations did not apply to the national average, but a modern orchard with high production level. The prices and unit costs of inputs used (materials, manual labour, machine operations) reflect the price levels of the years 2013-2014, material prices were considered without VAT, but manual labour costs with contributions. The yields, the yield quality and the selling prices were represented with a 5 years average.

The calculations basically reflect in several years on average values, i.e. a medium, average vintage. Extremes resulting from the vintage effect were being treated with sensitivity tests.

The current prices were used in the investment analysis for every single year, i.e. inflation was calculated neither in the output, nor in the input markets. The amortisation costs obviously could not be counted among the expenditures, however, their "tax shield effect" was not considered as well. The calculations did not involve direct subsidies and general expenses. The level of calculative interest rate (r) in the calculations was 6%. The average life span of the investments was considered 15 years. The analyses were based on the most likely expected realistic scenario. The hidden uncertainty of management and calculations were considered in sensitivity analyses (scenario analysis, elasticity tests and critical value analysis).

3. Results

This chapter summarises the most important results of the research in the sequence of the research *tasks* defined in the *objectives chapter*, and certifies or rejects the hypotheses deduced from the main objectives.

Thus exact data bases and statistics, which could have helped to identify the operating models of the modern Hungarian apple orchards farming on good level, were not found, the identification of specific operating models emerging from different combination of production and postharvest was done by professional estimation based on competence on the apple sector. There are several operating models, however, the most common types are: apple producing business with only orchard and no postharvest infrastructure, business with orchard and cold storage but without sorting and packaging capacities and business with orchard and full postharvest infrastructure. The most striking differences among these operating models is from the business management point of view are the initial capital demand of production (investment costs), the annual operating costs, the preparation level of the output and the achieved selling prices.

The main parameters of the analysed and compared orchards are included in *Table 1*.

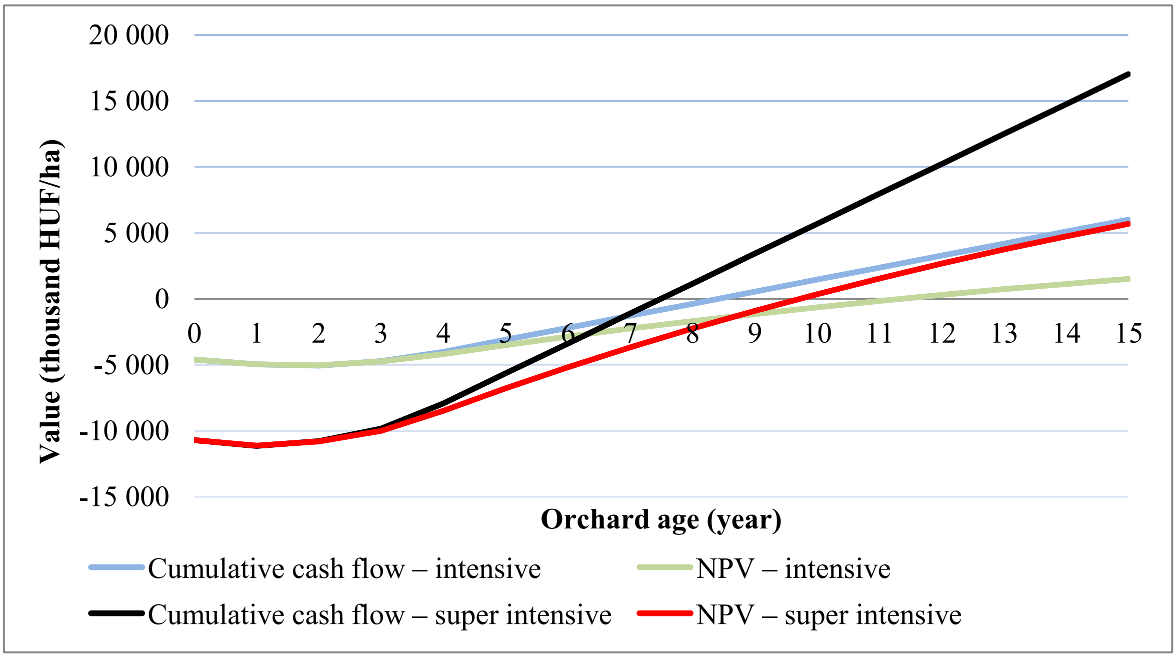
Table 1: **The parameters of the characterised super intensive apple orchard and the intensive apple orchards used as comparison basis**

Description	"Super Intensive"	"Intensive"
Subject	M9	M9
Spacing	3.25 x 1.0 m	4.0 x 1.0 m
Number of plants	3077 tree/ha	2500 tree/ha
Planting material	Knip tree	summer grafted 1 year old trees
Crown form	slender spindle/super spindle	slender spindle/super spindle
Support system	concrete columns support system with wires, suitable for holding hail protection nets	wooden columns support system with wires
Irrigation	drip irrigation	drip irrigation
Hail protection net	concrete columns with black mesh, 4.0 m height	none
Available yields	ca. 60 t/ha	ca. 40 t/ha
Dessert apple ratio	95%	80%
Sold products	The produced dessert apples were picked into bins, 'pre-sorted' during the hand-picking, and sold immediately after harvest. Postharvest processes do not arise. Apples for industrial purpose were delivered loose.	

Source: own editing

According to the dynamic investment analysis indicators, the economics of *intensive apple orchards* with about 40.0 t/ha yields and 80% dessert apple ratio can be considered as appropriate and acceptable. Under medium-average market and weather conditions, the investment returns around the 12th year, with 9-10% IRR and 1.5 million HUF/ha NPV. In a given production year, under prices of several years on average the critical yield, which means the turning point of profitability, is about 27 t/ha, which can be reached in modern orchards (*Figure 1* and *Table 2*).

In *super-intensive orchards*, however, 2.5-3.0 times higher unit profit could be achieved per hectares compared to intensive orchards with 1.5-2.0 times higher revenues and nearly 1.5 times higher per hectare production costs. This applies to a given production year and to the total results achieved during the whole lifespan of the orchard (NPV= 5.7 million HUF/ha). Nevertheless, the "capital proportional" investment analysis indicators (IRR, PI and DPP) were only 15-25% more favourable than in case of intensive plantations. The main advantage of the super intensive orchards are the 1.5-times higher yields per hectare, and the much better - approaching 100% - dessert apple ratio. In contrast, the main drawbacks of the super intensive orchards are the 2.0-2.5 times higher per hectare capital demand of planting compared to intensive orchards. The annual operating costs were only 20-30% higher. The higher capital demand and higher annual production costs also means greater management risk, because in case of a bad vintage, there will be higher losses as well (*Figure 1*, *Table 2*).



Source: own calculations

Figure 1: **The economics of super-intensive and intensive apple orchards (r = 6%)**

Table 2: **The development of the economic indicators of the super-intensive and intensive apple orchard**

Description	**Unit**	**Super Intensive**	**Intensive**
Static indicators			
Cumulative cash flow	thousand HUF/ha	17 030	6007
Static payback time	Year	8	9
Static index of return	-	2.59	2.31
Dynamic Indicators			
Net present value (NPV)	thousand HUF/ha	5684	1507
Internal rate of return (IRR)	%	11.53	9.37
Profitability index (PI)	-	1.53	1.33
Discounted payback period (DPP)	Year	10	12

Source: own calculations

It should be pointed out in case of super intensive orchards, that even the basis on several years on average assumed 61 t/ha yield provided a quite late (10 years) return, meaning, that in orchard with such high capital demand and input level, only a production of very high level of competence and technological standard of discipline with almost no technological failures could provide economic operation. Higher security of return on investment can be achieved with investment supports, planting of super intensive orchards clearly on own resources could be uncertain under the Hungarian market conditions and selling prices.

The following main conclusions were drawn regarding to the orchard intensity enhancing technological, infrastructural and technical elements (Knip trees, hail protection net, work platform).

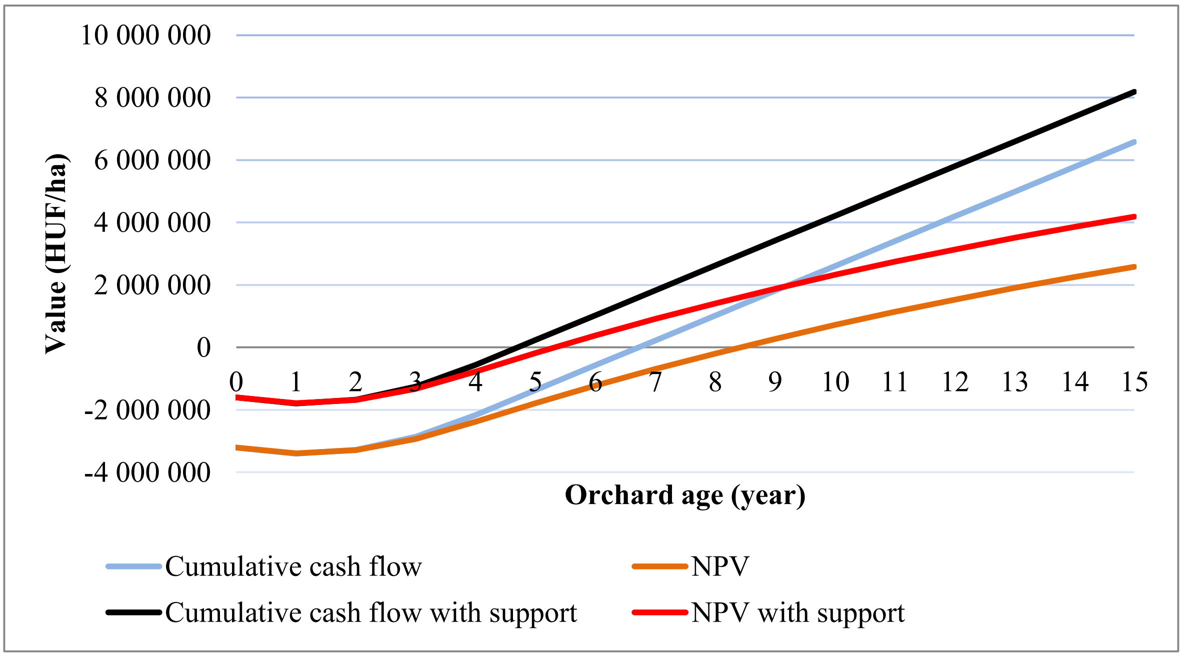
The higher purchase price of *Knip trees* could return under Hungarian ecological and economic conditions, but only if the above described yields and quality ratio are guaranteed with high level of competence and production technology. Often crop failures emerging from technological mistakes make the investment uneconomical (if in yields of the first five year a significant or almost total crop failure occurs, it already makes the return on investment critical). Therefore, the additional costs of Knip trees returns more secure mainly under hail protection net, maybe in orchards with frost protection. Nevertheless, the acquisition of Knip trees will be in several Hungarian businesses a financial question difficult to solve because of the increased initial capital demand of planting (*Table 3*).

Table 3: **The additional costs, revenues, incomes and economics of planting with Knip trees**

Description		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Purchase price: thousand HUF/ha	Knip trees	4 061.6					
	summer grafted 1 year old trees	2 153.9					
	additional purchase cost	**1 907.7**					
Cultivation/production costs (thousand HUF/ha) *	Knip trees		428.8	910.5	1 576.0	1 731.7	1 791.2
	summer grafted 1 year old trees		367.5	546.6	904.9	1 578.9	1 706.2
	Additional costs		**61.3**	**363.9**	**671.2**	**152.9**	**84.9**
Yield t/ha	Knip trees		0.0	19.1	38.2	55.1	61.5
	summer grafted 1 year old trees		0.0	6.2	18.5	38.5	52.3
	Additional yield		**0.0**	**12.9**	**19.7**	**16.6**	**9.2**
Revenue thousand HUF/ha	Knip trees		0.0	1 135.1	2 270.2	3 277.2	3 661.6
	summer grafted 1 year old trees		0.0	366.2	1 098.5	2 288.5	3 112.4
	Revenue surplus		**0.0**	**768.9**	**1 171.7**	**988.6**	**549.2**
Income surplus of Knip trees		-1 907.7	-61.3	405	500.5	835.8	464.3
Accumulated income surplus		**-1 907.7**	**-1 969.0**	**-1 563.9**	**-1 063,4**	**-227.6**	**236.7**
Discounted income surplus (thousand HUF/ha)		-1 907.7	-57.8	360.5	420.3	662	347
NPV (thousand HUF/ha)		**-1 907.7**	**-1 965.5**	**-1 605.0**	**-1 184.8**	**-522.8**	**-175.8**

Source: own data collection and calculation

In case of the hail protection net investment, the 3210 thousand HUF/ha additional investment costs of hail protection net – compared to the regular support system – faces 794 thousand HUF/ha profit surplus (cash flow) due to the improvements of production quantity and quality under the hail protection net.



Source: own calculations

Figure 2: **The economics of the hail protection net investment in case of 3.5 m tree height, when investing 100% on own sources and on 50% support + 50% own sources (r = 6%)**

Based on the economic indicators demonstrated in *Figure 1* and *Table 7*, it can be concluded, that the economics of hail protection nets shows a positive picture. The 3210 HUF/ha additional costs of hail protection net investment returns in 7 years under static approach and in 9 years under dynamic approach, when investing 100% on own resources. In case of 50% non-refundable investment support, the payback period declines to 5 or 6 years. Each indicator of return could be considered very favourable, particularly with regard to the fact, that in the first 4 years no total yields can be achieved. Both cumulated cash flow and net present value (NPV) indicator reach very high values at the end of orchard lifespan (15 years). The IRR of close to 14% (25% with investment support) can be called fine enough, especially regarding to the fact, that the IRR of super intensive orchard with hail protection net was 11.5%. This means, that the hail protection net as a supplementary, additional technological element - through its protecting effects - can be described with more favourable economic parameters, than the whole system together.

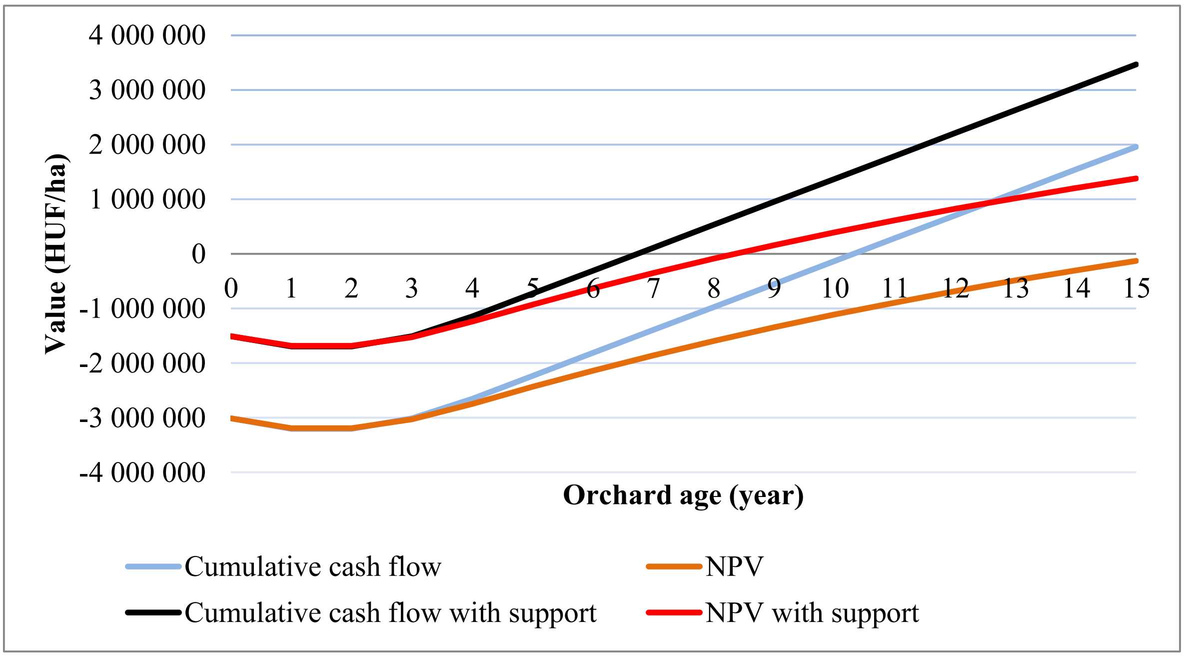
Table 4: **Economic indicators of the hail protection net investment at 3.5 m tree height**

Description	**Unit**	**without support**	**with support***
Static indicators			
Cumulative cash flow	thousand HUF/ha	6575	8180
Static payback time	Year	7	5
Static index of return	-	3.05	6.10
Dynamic Indicators			
Net present value (NPV)	thousand HUF/ha	2585	4190
Discounted payback period (DPP)	Year	9	6
Profitability index (PI)	-	1.81	3.61
Internal rate of return (IRR)	%	13.89	25.11

Source: own calculations Note: *with 50% investment support

The calculations were made also for a not 4.0 m high hail protection system with 0.5 m extra tree height, but for a 3.5 m high hail protection net system with a tree height of 3.0 m - equal to the tree height of standard support systems. The substantive difference compared to the above detailed base case is, that in this case are neither 8.0 t/ha extra yields, nor additional variable costs. The initial 50.0 t/ha harvest is protected by the hail protection nets, so the 19 percentage-point quality improvement can be observed, however, the extra harvest is merely 3.5 t/ha. Investment costs 200 thousand HUF per hectare decreased. *Figure 3* and *Table 5* include the results of these calculations.

The results show significantly decreasing, but not unfavourable economic indicators. In this scenario may be similar economic indicators achieved only with investment support as the first scenario (3.5 m tree height) without support. Without investment support, the economics of the project were moving around the turning point: NPV was slightly negative, IRR slightly below r, PI was nearly 1.0 and the return occurred – calculated further – in the 16th year.



Source: own calculations

Figure 3: **The economics of the hail protection net investment in case of 3.0 m tree height, when investing 100% on own sources and on 50% support + 50% own sources (r = 6%)**

Table 5: **Economic indicators of the hail protection net investment at 3.0 m tree height**

Description	**Unit**	**without support**	**with support***
Static indicators			
Cumulative cash flow	thousand HUF/ha	1960	3466
Static payback time	Year	11	7
Static index of return	-	1.65	3.30
Dynamic Indicators			
Net present value (NPV)	thousand HUF/ha	-126	1379
Discounted payback period (DPP)	Year	> 15	9
Profitability index (PI)	-	0.96	1.92
Internal rate of return (IRR)	%	5.50	14.2

Source: own calculations Note: *with 50% investment support

It can be concluded, that the installation of hail protection nets as additional technological element of intensive apple orchards can be considered as an economic investment - trough their protective effect. However, to achieve really favourable economic indicators, definitely bigger tree height is needed making possible the realisation of around 8.0 t/ha extra yield. The main root of this phenomena are obviously the high investment costs of hail protection nets, which result in a large mass of fixed costs during the production period. Therefore the basic economic interest is reaching higher yields and thereby higher profits per unit area.

The purchase of *work platforms* cannot be considered as an economic investment under Hungarian circumstances. It might be economic, utilised on maximum area (ca. 30 hectares) instead of machines with high operating costs by certain companies in special cases, but in most cases – under Hungarian labour cost levels – did not show favourable payback conditions. The use of work platforms in orchards under 16-25 ha size could be economic in hardly any condition.

Table 6: **Economic indicators of work platforms compared to Lamborghini tractor with special trailer (r = 6%, t = 10 years)**

Description	Unit	without support	with support*
Static indicators			
Cumulative cash flow	thousand HUF	7159	11 260
Static payback time	Year	7	5
Static index of return	-	1.61	2.48
Dynamic Indicators			
Net present value (NPV)	thousand HUF	2176	6277
Discounted payback period (DPP)	Year	8	5
Profitability index (PI)	-	1.19	1.82
Internal rate of return (IRR)	%	9.76	21.15

Source: own calculations Note: *with 35% investment support

Table 7: **Economic indicators of work platforms compared to T-25 tractor with special trailer (r = 6%, t = 10 years)**

Description	Unit	without support	with support*
Static indicators			
Cumulative cash flow	thousand HUF	- 1655	2446
Static payback time	Year	> 10	8
Static index of return	-	0.86	1.32
Dynamic Indicators			
Net present value (NPV)	thousand HUF	- 4311	-210
Discounted payback period (DPP)	Year	> 10	> 10
Profitability index (PI)	-	0.63	0.97
Internal rate of return (IRR)	%	< 0	5.41

Source: own calculations Note: *with 35% investment support

Three operating models were analysed in this thesis in order to evaluate the relationship and it economic impacts of cultivation and *postharvest* and to verify the hypotheses. On the one hand, apple production without postharvest and with immediate marketing after the harvest (model "A"); on the other hand, apple production with storage and extended marketing period (model "B"); and thirdly, production and the existence of full postharvest infrastructure (storage, sorting, packing) with the highest level of commodification and continuous marketing (model "C"). It can be concluded, that the coexistence of production (orchard) and cold storage, that is, the second operating model, proved to be absolutely uneconomical, given the fact that the establishment of cold storage capacity had very high additional investments costs, but resulted in relatively low additional profits, compared to the first operating model. The main root of this is, that this model sells loose goods without sorting and packaging, however, the storage itself - as the device of the continuous service of the markets - has been no longer "paid" appropriate. No absolute efficiency rankings can be set uo between the two other operating models: the orchard without postharvest infrastructure had lower NPV but higher IRR, DPP and PI than the orchard with full postharvest infrastructure. The former operating model was better when considering the capital proportional indicators, the latter when focusing on the profitability (*Table 8*).

Table 8: **Changes in the investment analysis indicators in the three cases in realistic model, without investment support (*t = 15 years; r = 6%*)**

Description	Unit	"model A"	"model B"	"model C"
Net present value (NPV)	thousand HUF/ha	1 507.0	-6 436.0	3 274.0
Internal rate of return (IRR)	%	9.37	1.19	8.01
Discounted payback period (DPP)	Year	12	> 15	15
Profitability index (PI)	-	1.33	0.60	1.19

Source: own calculations

Based on the data shown in *Table 9*, the economic indicators of all three operating models improved significantly when having a 40% investment support. "Model B" reached whit this the border of profitability, and almost returned in the 15th year. The NPV of "model A" increased more than two-fold, the IRR and PI nearly 2-fold, and the DPP was reduced from 12 years 8 to years. In case of "model C", a change whit similar magnitude and direction occurred, but in this case the NPV increased more than three-fold, and the DPP came also much closer to the payback period of "model A". Comparing "model A" and "model C", the differences decreased due to the investment support more favourable for "model C": NPV was three times higher than of the "model A", and relatively smaller differences could be observed in the other indicators as well.

Table 9: **Changes in the investment analysis indicators in the three cases in realistic model, with investment support (*t = 15 years; r = 6%; support intensity = 40%)***

Description	Unit	"model A"	"model B"	"model C"
Net present value (NPV)	thousand HUF/ha	3 345.0	-75.0	10 021.0
Internal rate of return (IRR)	%	15.95	5.92	14.39
Discounted payback period (DPP)	Year	8	> 15	9
Profitability index (PI)	-	2.21	0.99	1.99

Source: own calculations

The elasticity tests pointed out (*Table 10*), that the profitability was affected mostly by the selling price of dessert apples as main product in every operating model. Subsequently, in case of all three models, yield and crop quality -i.e. the revenue side - were the most influencing factors, the annual operating cost and investment cost factors affect the economics the least.

Table 10: **The results of the elasticity tests for the factors most affecting profitability (*the impact of 1% favourable change of the factors on the NPV*)**

Description	Unit	"model A"	"model B"	"model C"
Average selling prices of dessert apples	%	10.68	3.01	11.05
Yield	%	9.68	2.34	9.56
Dessert apple ratio	%	7.29	2.22	8.67
Operating costs in production age	%	5.97	1.80	4.91
Investment costs	%	3.05	2.47	5.16

Source: own calculations

Table 11 shows a similar picture, where the critical values of the profitability most affecting factors and their ratio compared to the initial values were given. The latter suggested what degree and direction of differences form the realistic value could be enabled keeping the investment still profitable. The lower limit of the profitability is at the value of NPV = 0. In case of the profitable "model A" and "model C", a very small (9-13%) drop of yield or selling price was enough to turn them into uneconomical production. These operating models were equally sensitive to the dessert apple ratio, where a 14-17% maximum drop could be tolerated. Such a degree of yield, price and quality decline is realistic from the professional horticultural point of view, so these factors are critical for profitability by all means. In the case of operating and investment costs even further 16-32% increase was permitted to access the profitable level.

Table 11: **Critical values of the main factors determining the profitability and their ratio compared to the initial realistic version**

Description	**Unit**	**"model A"**		**"model B"**		**"model C"**	
		Value	Propor-tion	Value	Propor-tion	Value	Propor-tion
Dessert apple prices	HUF/kg	62.38	90.6%	117.51	133.2%	150.10	91.0%
Yield*	t/ha	34.40	87.3%	56.20	142.6%	35.00	88.8%
Dessert apple ratio *	%	66.90	83.6%	> 100	-	69.00	86.3%
Operating costs *	thousand HUF/ha	1 673.00	116.8%	764.00	42.6%	3 161.00	119.9%
Investment costs	thousand HUF/ha	6 102.00	132.8%	9 466.00	59.5%	20 143.00	119.4%

Source: own calculations * NOTE: projected to the production years

Based on the above findings and conclusions, the following conclusions can be made considering the hypotheses.

The *first hypothesis*, namely, that the planting of super-intensive orchards can be considered an efficient investment, under Hungarian ecological and market conditions as well. However, 60-70 t/ha average yield and around 95% dessert apple ratio is needed to achieve this, which implies a very high level of expertise in production technology, discipline and input level. This is present in approx. 10% of the Hungarian apple producing businesses.

The *second hypothesis*, That is, that the existence of postharvest technology significantly improves the economics of production, was only partly verified as follows:

- The mere existence of the storage capacity only did not improve the profitability of the production, but also worsened the economic indicators because there is no proportion between the investment costs and the available higher average selling prices in the Hungarian market.
- However, this does not mean that the installation of storages were not necessary, because above a certain scale of operation, the presence of cold storage is basic condition for the selling or even the market penetration of large amount of goods (continuous customer service through 10-12 months).
- The total postharvest infrastructure (storage, sorting and packaging) increased the income significantly.

The *third hypothesis* that the highest level of postharvest infrastructure (i.e. the co-existence of production, storage, sorting, grading and packaging processes) results in the most favourable investment analysis indicators, was only partly verified as well. The absolute amount of available earnings (net income NPV) was significantly increased due to the presence of the full postharvest infrastructure compared to the without postharvest state, but the capital proportional indicators (IRR, DPP, PI) were deteriorating. The reason for that is that the postharvest infrastructure led to a higher amount of income, but the profits did not increase in the same measure as the capital demand of production did because of the postharvest infrastructure.

The above results predict that two operating models have good development prospects. The first one is, when installing an orchard without postharvest and selling the fruits immediately after harvest to a well-functioning integrator organisation. The second option is, when establishing a full postharvest infrastructure next to the orchard, because this is the only way to penetrate into almost every market and creating goods of high added value.

4. New scientific results of the dissertation

New results of the dissertation are not related to the methodology, but the results can be considered new or novel from the professional point of view, for which literature sources so far has been not available. These can be summarized as follows:

1. The economic characteristic of super intensive apple orchards with hail protection net was determined, regarding to the cost-benefit relations and the profitability of the investment. It was found, that 2.5-3.0 times higher unit profit could be achieved per hectares compared to intensive orchards with 1.5-2.0 times higher revenues and nearly 1.5 times higher per hectare production costs. It was also verified, that the planting of super-intensive orchards can be considered an efficient investment, under Hungarian ecological and market conditions as well. However, 60-70 t/ha average yield and around 95% dessert apple ratio is needed to achieve this, which implies a very high level of expertise in production technology, discipline and input level. This is present in approx. 10% of the Hungarian apple producing businesses.
2. The economics of the use of Knip trees was evaluated compared to the summer grafted 1 year old trees. Concluded, the higher purchase price of Knip trees could return under Hungarian ecological and economic conditions, but only if the above described yields and quality ratio are guaranteed with high level of competence and production technology. Therefore, the additional costs of Knip trees returns more secure mainly under hail protection net, maybe in orchards with frost protection.
3. The profitability of the hail protection net as a supplementary technological element of super intensive orchards was analysed. In this analysis the methodological approach can be considered novel as well, because according to the principle of surpluses, only the positive and negative effects of hail protection nets were quantified and not the technological-economic relationships of the orchard with hail protection net as an organic system. Installing hail protection nets as additional technological elements of intensive apple orchards can be considered by all means as an economic investment - trough their protective effect. However, to achieve really favourable economic indicators, definitely bigger tree height (3.5 m) is needed making possible the realisation of around 8.0 t/ha extra yield.
4. The economics of work platforms were analysed as well. It was found, that the purchase of work platforms cannot be considered as an economic investment under Hungarian circumstances. It might be economic, utilised on maximum area (ca. 30

hectares) instead of machines with high operating costs by certain companies in special cases, but in most cases – under Hungarian labour cost levels – did not show favourable payback conditions.

5. Three operating models were analysed in order to evaluate the relationship and economic effects of postharvest. It can be concluded, that the coexistence of production (orchard) and cold storage, proved to be absolutely uneconomical, given the fact that the establishment of cold storage capacity had very high additional investments costs, but resulted in relatively low additional profits, compared to the first operating model. No absolute efficiency rankings can be set up between the two other operating models: the orchard without postharvest infrastructure had lower NPV but higher IRR, DPP and PI than the orchard with full postharvest infrastructure. The former operating model was better when considering the capital proportional indicators, the latter when focusing on the profitability. The presence of the full postharvest infrastructure (storage, sorting and packaging) significantly improved the available profit.

5. The practical usefulness of results

The main result of this dissertation on the research field is, that it analysed such areas, of which very few pieces of information have been available in Hungary before. The analysed orchard types, technical and technological elements serve for modernization and the increase of incomes. The extent and the way of their improving profitability were determined.

The results provide guidance for policy-makers to select the development strategies of the sector in order to find the modernisation options to the more precise delimitation of developments to be supported.

Considering the education, the results of the dissertation can be well utilised, because the analysis can be easily adapted to the horticultural and economic education due to its structure and content.

The results of the dissertation provide the most practical usefulness for the apple producing businesses, as they help making both production both investment decisions. On this basis, it is clear that the planting of a super-intensive orchards significantly improves profitability, but their efficient operation requires a very large capital and expertise. The use of hail protection net and Knip trees can be recommended even under Hungarian conditions, however, the return of work platforms is very critical.

The postharvest processes are now an integral and indispensable part of the apple production, but only the establishment of a full postharvest infrastructure provides more favourable economic indicators, the cold storage only is not necessarily an effective investment.

The results predict that two operating models have good development prospects. The first one is, when installing an orchard without postharvest and selling the fruits immediately after harvest to a well-functioning integrator organisation. The second option is, when establishing a full postharvest infrastructure next to the orchard, because this is the only way to penetrate into almost every market and creating goods of high added value. Super intensive orchards with Knip trees and hail protection net have their justification under the Hungarian market, economic and ecological conditions, however, only with great expertise and technological discipline.

6. Publications

UNIVERSITY OF DEBRECEN
UNIVERSITY AND NATIONAL LIBRARY

Registry number: DEENK/81/2016.PL
Subject: Ph.D. List of Publications

Candidate: Viktor Szabó
Neptun ID: MUV6KO
Doctoral School: Kerpely Kálmán Doctoral School of Corp Production, Horticulture and Regional Sciences

List of publications related to the dissertation

Hungarian book chapter(s) (3)

1. **Szabó V.**: Aktuális fejlesztési-korszerűsítési kérdések és gazdasági megítélésük.
   In: Versenyképes almatermesztés. Szerk.: Gonda István, Apáti Ferenc, Szaktudás Kiadó Ház Zrt., Budapest, 295-305, 2013. ISBN: 9786155224409

2. **Szabó V.**, Apáti F.: A posztharveszt tevékenységek gazdasági kérdései.
   In: Versenyképes almatermesztés. Szerk.: Gonda István, Apáti Ferenc, Szaktudás Kiadó Ház Zrt., Budapest, 279-294, 2013. ISBN: 9786155224409

3. Apáti F., **Szabó V.**: A termésvédelmi technológiák gazdasági megítélése.
   In: Versenyképes almatermesztés. Szerk.: Gonda István, Apáti Ferenc, Szaktudás Kiadó Ház Zrt., Budapest, 263-278, 2013. ISBN: 9786155224409

Hungarian scientific article(s) in Hungarian journal(s) (3)

4. **Szabó V.**: Az önjáró munkaállványok alkalmazásának gazdaságossága szuperintenzív almaültetvényekben.
   Agrártud. Közl. 68, 91-98, 2016. ISSN: 1587-1282.

5. **Szabó V.**: Az almatermelés gazdaságossága a posztharveszt technológia függvényében.
   Agrártud. Közl. 63, 125-132, 2015. ISSN: 1587-1282.

6. Apáti F., Soltész M., Nyéki J., Szabó Z., Gonda I., Felföldi J., **Szabó V.**, van Mourik D.: Jégvédő hálók beruházásának megtérülése almaültetvényekben.
   "Klíma-21" Füz. 64, 132-137, 2011. ISSN: 1218-5329.

Address: 1 Egyetem tér, Debrecen 4032, Hungary Postal address: Pf. 39. Debrecen 4010, Hungary
Tel.: +36 52 410 443 Fax: +36 52 512 900/63847 E-mail: publikaciok@lib.unideb.hu, ¤ Web: www.lib.unideb.hu

Foreign language scientific article(s) in Hungarian journal(s) (1)

7. **Szabó, V.**: The economic efficiency of apple production in terms of post-harvest technology. *Apstract. 8* (2-3), 99-106, 2014. ISSN: 1789-221X.

List of other publications

Foreign language scientific article(s) in Hungarian journal(s) (1)

8. **Szabó, V.**: Economics of hail protection net installation in super intensive apple orchards. *Agrártud. Közl. 68*, 27-35, 2016. ISSN: 1587-1282.

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of Web of Science, Scopus and Journal Citation Report (Impact Factor) databases.

05 April, 2016