Thesis of Doctoral (PhD) dissertation

COMPARATIVE STUDY OF ENVIRONMENTALLY FRIENDLY APPLE PRODUCTION TECHNOLOGY

Péter Dremák

Supervisor:

Dr. habil. István Gonda

UNIVERSITY OF DEBRECEN

JENŐ HANKÓCZY DOCTORAL SCHOOL FOR PLANT PRODUCTION, HORTICULTURE AND FOOD SCIENCES

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Introduction

The word apple production growth is larger in the past decades than the word human population. However this dinamic growth has not only advantages but serious disadvantages as there are overproduction crisis and marketing disorders in fruit production all over the world. Production volumen reaches and exceeds 75.5 million tons by now, from wich China produces 36 million tones (1st place) USA 4.2 million tones (2nd place), while Hungary produces only 299.000 tones in the 34th places (FAOstat, 2003). The reasons of the differences can be explained by the fact that most plantations is in small sized farms, which have unsuitable marketing opportunities.

Great interest on quality product (optimal size, colouring, shape, flavour etc.) resulted in lower chemical use or completely chemical free production technology. This was the reason why the fundamentals of enviromental friendly production technology have been widely spread especially integrated production. The integerated technology, which unites all scientific disciplines, is different from the organic production technology. Chemical products are not used in organic production (as in the prehistoric fruit production). Chemicals can cause catastrophic world-wide pollution such as DDT and neonicotinoids. Organic production completelly bans the use of synthetic products (synthetic fertilizers and plant protection products), only natural products can be used in this production system.

Fruit production has the largest chemical loads among the horticultural sectors. It is nessesary to state that organic production with its natural fundamentals got priority due to increasing enviromental pollution. Unfortunatelly there are no communication, ability for cooperation among the representatives (researchers/producers/advisors … etc.) of integrated or organic production system. However, this cooperation and communication can be used for the mutual benefits for the two production system and for reducing or avoiding uncertainties. The basis of disgreement is the strict regulation, often pragmatical principles, of the organic production while the conventional production has vigorous thinking and exercising on chemical use.

The aim of this doctoral thesis was to compare the possibilities and difficulties of the two production systems (integrated and organic) and to answer what mutual view-point can be considered during the successful production for a few apple cultivars.

1. Objectives

Our objectives were to compare the biological and production technology characteristics of apple cultivars in integrated and organic production system according to the belows:

- vegetative indicators (trunk and branch cross section areas)
- generative indicators (flower buds number, ages of the fruiting base, flower production specialities)
- the effect of pruning methods on the growing features of cultivars
- the effect of frost damage on apple culivars
- the effect of different production systems on yield (yield/tree and yield/crop area/land)
- the main pest contol problems of apple cultivars (*Venturia inaequalis* and codling moth)
- the consumers appreciations and determination of inner contents of apple cultivars (flesh quality and firmness, sugar/acid harmony and quality index, overall acceptability by consumers and inner contents)

According to above parameters we tried to determine the most suitable apple cultivars, phytotechnical specialities and disadvantages for integrated or organic production. As a consequence practical suggestions will be defined for the two production systems.

2. Materials and methods

Experimental site

The basis of current dissertation's measurement was in Debrecen University Institute in the Fruit Experimental Station at Pallag, where the apple cultivar collections were located. The measured apple cultivars were planted in spring of 1997 on rootstock M26, with 4.0 x 1.5 m spacing distances.

Applied rootstocks

For the research purpose, rootstocks M26 had been choosen, because they had stronger growing capability compared to M9, which is used mainly for intensive integrated orchards, where the spacing patterns generally smaller.

Characteristics of cultivar groups

The cultivar collection consisted of 40 apple cultivars and was grouped to three classes as historical-, resistant- and worldwide known apple cultivars. Some of the historical cultivars are not planted in current new orchards. In this thesis (as in the table) we used for our resarch the most popular world-wide known, the historical, and the newly tested scab and mildew resistant German cultivars.

1st. chart. Grouping of apple varieties (Debrecen-Pallag, 2010)

worldwide known cultivars	***resistant German cultivars***	***historical Hungarian cultivars***
Gála Must	Pilot	Batul
Golden Reinders	Reka	Mosolygós batul
Csányi Jonathan	Relinda	Nyári fontos
Ozark Gold:	Renora	Téli aranyparmen
Elstar:	Reglindis	Téli banán
Mutsu:	Releika	Téli piros pogácsa
Jonagold:	Rewena	Darusóvári
Golden Orange	Retina	Fertődi téli
Ruby Gala	Remo	Francia renet
Idared	Liberty	London pepin
Granny Smith	Reanda	Gravensteini
Pinova	Resi	Téli fehér kálvil
Topaz	Faw 7262	Húsvéti rozmaring

Applied plant protection

Plant protection was applied according to Hungarian Integrated Production Directives in the integrated orchard, while the Hungarian Ecological Production Directives was used in the organic orchard.

3. Methods of Examinations

- Measurement methods of the apple trees for vegetative growing parameters.

The growing parameters have been compared to each other by the trunks' and branches' diameters (cm^2). Thickness of trees were considered as basic parameter, which have been measured on a certain point between ground level and on the lower first branch. The same approach have been used an axis thickness between 1.0 and 1.5 m high. Thanking to the above mentioned measurement results, it seemed to be important also to show and examine

the younger trees' data. The thickness of the branches have been measured on the same approach, the result have been summarized in cm^2. The number of branches in the crown is also very important parameter, since it reflects the capability of branch growing within the cultivars, or in other words it shows the regeneration ability.

- Measurement method of the generative parameters of the apple trees'.

At the different producing methods, the number of flower buds and their placing were measured on the 1st grade branches. These results are summarized as piece/branch diameter in cm^2.

- Effects of pruning methods on growing parameters.

Different types of pruning methods were used on the selected 5 resistant and tolerant cultivars and their effects on the growing abilities.

- strong pruning: 1 and 2 years old parts removed, the shoots were cut back to their 30-50% lenght in both orchards
- moderate pruning: only the 1 year old shoots were removed

At the end of August the following parameters were analyzed: lenghts of shoots (cm), number of shoots (piece), and lenght of shoots devided by pruning methods.

- Frost damage.

At the end of February, frost damage was analyzed on the fruiting woody parts. They were collected from the 4 quater of the tree. The buds were cut transversely and lenghtwise.

- Yield. After the harvest, yield/tree and the yield/ha were measured.
- Assesment of the most important plant protection problems.

Apple scab infection period were defined according to Mills-infection table. 30 fruits/ tree were examined regarding the incidence of apple scab infection. Incidence of codling moth damage was evaluated on 30 fruits/tree.

- Customers opinions and features of inner contents

Cultivar features were characterised by 1-5 grades in organoleptic assesment. Flesh firmness was measured with a penetrometer (lb/cm^2). Quality parameters such as Quality Index (QI)= total sugar+10*total acid, soluble solid content (Brix%), Ca-content (mg/100g) and vitamin-C content (mg/100g) were also measured.

4. Results and discussion

Trunk cross section area

Trunk cross section area can be seen in figures 1 and 2.

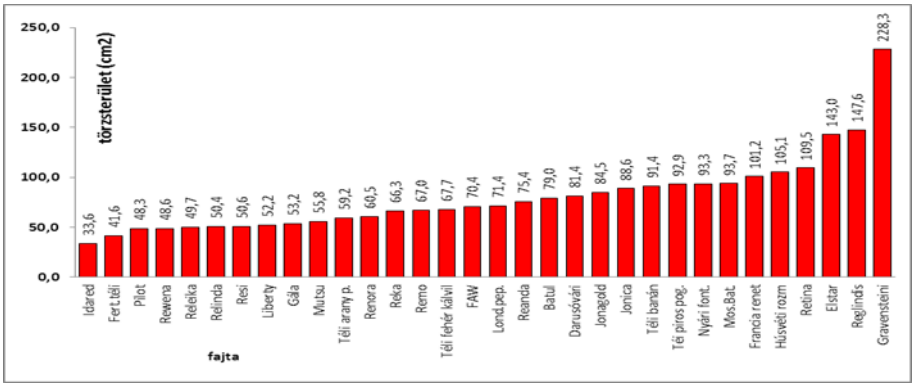

Figure 1. Trunk cross section area of 14-year old apple cultivars in integrated orchard (Debrecen-Pallag, 2010)

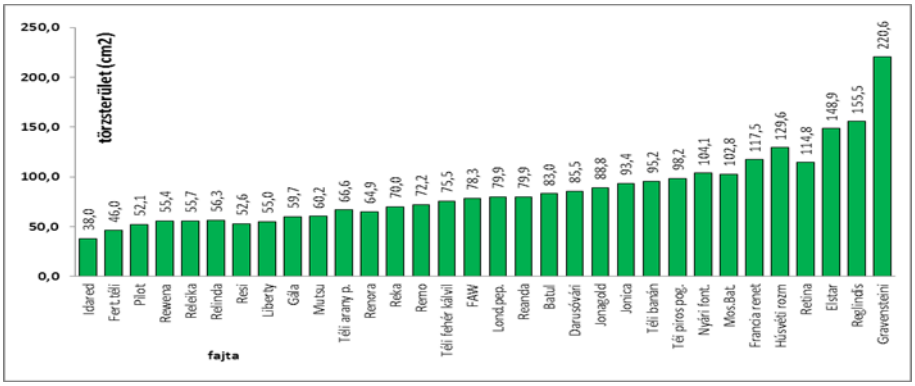

Figure 2. Trunk cross section area of 14-year old apple cultivars in organic orchard (Debrecen-Pallag, 2010)

According to the figures, trunk cross section area was larger in organic production for all cultivars compared to integrated production. This tendency could be seen in young orchard, but the difference was lower.

Axis thickness above 1 meter is a characteristics measure the trees. Results are shown in figure 3. and 4. for integrated and organic orchards.

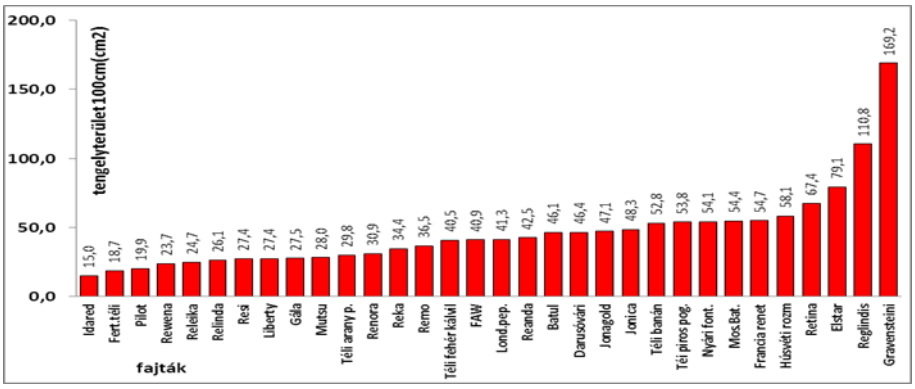

Figure 3. Axis thickness above 1 meter of 14-year old apple cultivars in integrated orchard (Debrecen-Pallag, 2010)

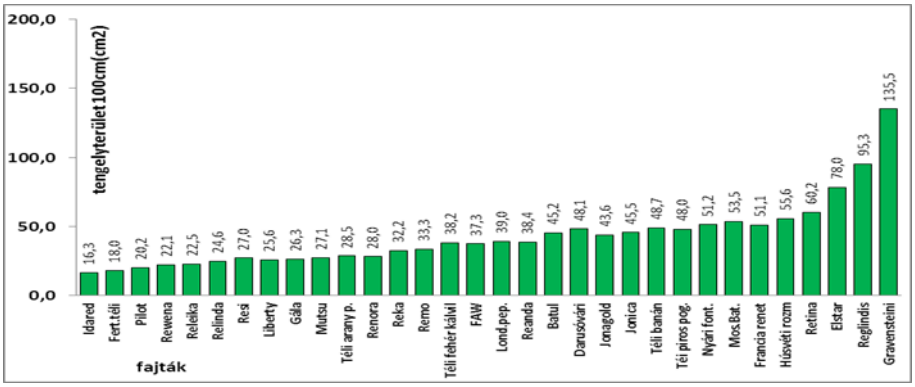

Figure 4. Axis thickness above 1 meter of 14-year old apple cultivars in organic orchard (Debrecen-Pallag, 2010)

Axis thickness showed similar tendency in organic production compared to integrated production. Axis thickness abowe 1 meter was clearly lower in organic production compared to integrated.

Lack of fruit load is considerable in young trees but this has different effect on the initial growth characteristics in the two production systems.

Later axis formation and axis thickness are equalized or are turn round. In several cases this can be experienced for axis thickness above 1 meter in integrated production. The best tendency can be seen in axis measured above 150 cm as trees were thicker in all cases in integrated production while thickness was more moderate in organic production.

Area of primary branches

Knowledge on initial thickness of primary branches are essential for maintaining optimal or harmonic crown structure. These data are shown in figure 5. for two environmentally friendly production system.

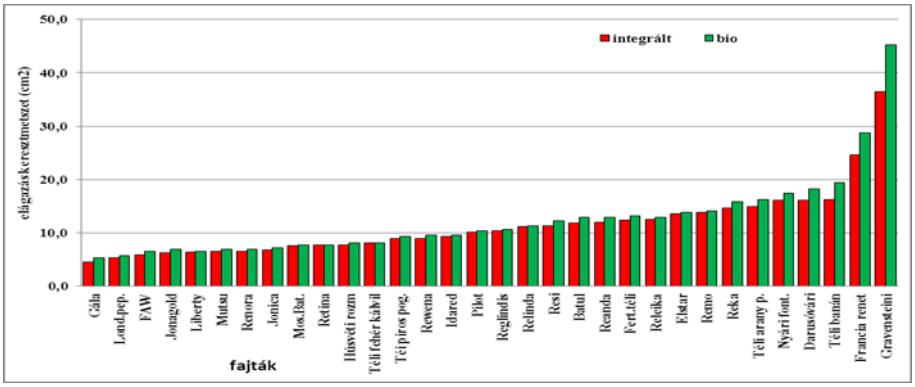

Figure 5. Area of primary lateral branches (Debrecen-Pallag, 2010)

For almost all cultivars, can be characterised with thicker under lateral branches in organic orchards. Thickness under lateral branches was larger in organic orchard similarly to trunk thickness. This larger tree thickness is practically important because larger distance needed for within-rows and between rows. According to the data lateral branches from lower and middle and upper third of the tree are more equalized in integrated production compared to organic. In this case tapered and well lightened crow structure can be created by uniform lateral branches with thinner and shorter form.

The number of primary branches in environmental friendly production technology

Number of primary branches can be seen in figure 6.

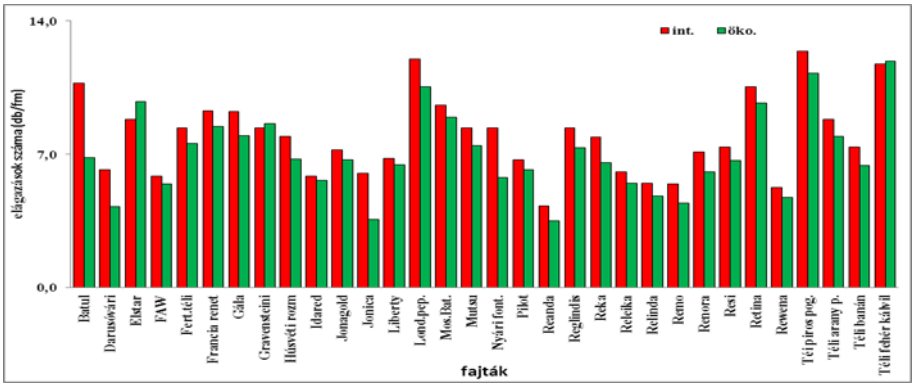

Figure 6. Number of primary branches originating crown axes in environmentally friendly apple production system (Debrecen-Pallag, 2010)

It clearly can be seen that branching capacity of the cultivars are better in integrated production system compared to organic production. This also shows a better conditional status of the trees in integrated production.

Effect of production technology of degree of pruning on lenght and number of shoots

The effect can be seen in figure 7.

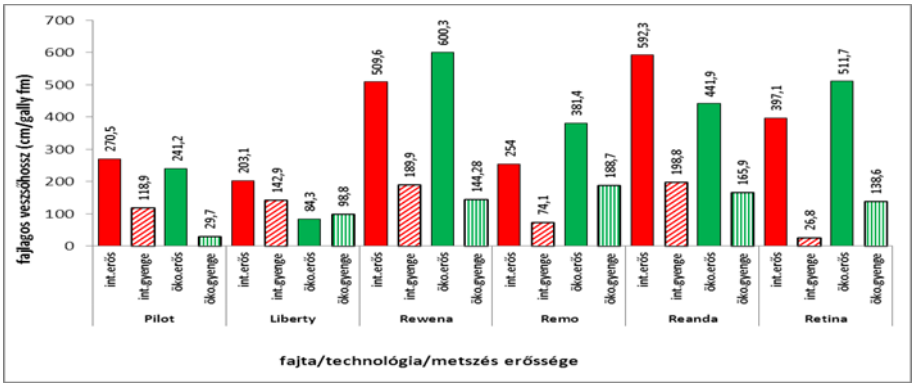

Figure 7. The effect of production technology of degree of pruning on total lenght of shoots (Debrecen-Pallag, 2008-2010)

The growth of shoots was low in both integrated and organic production and in the treatments of moderate pruning. However shoots are longer in integrated production for most cultivars. In organic production the lower shoot growth int he moderate pruning treatments can be explained by weaker conditional status of the trees.

Effect of the strongness of pruning on the number of shoots

The effect can be seen in figure 8.

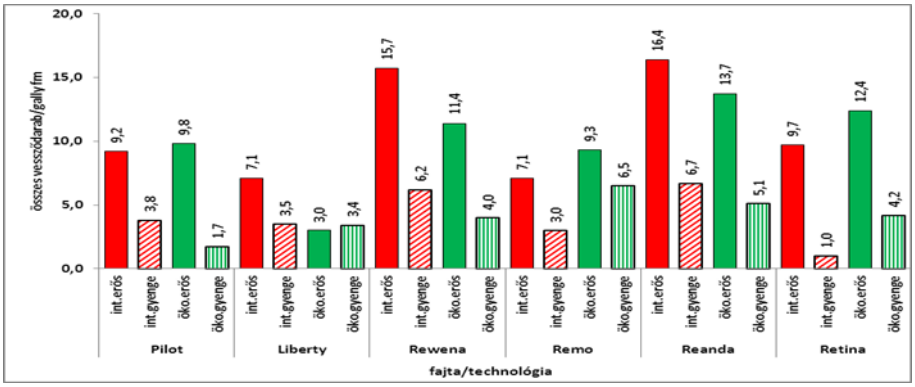

Figure 8. The effect of production technology of degree of pruning on total number of shoots (Debrecen-Pallag, 2008-2010)

In organic production both the number and the length of shoots was lower compared to integrated production. Shoot growth differences due to moderate and strong pruning can result in stronger pruning method in organic production.

Frost damage of apple cultivars

- Effect of production technology on frost damage of spears.

The effect of frost damage can be seen in figure 9.

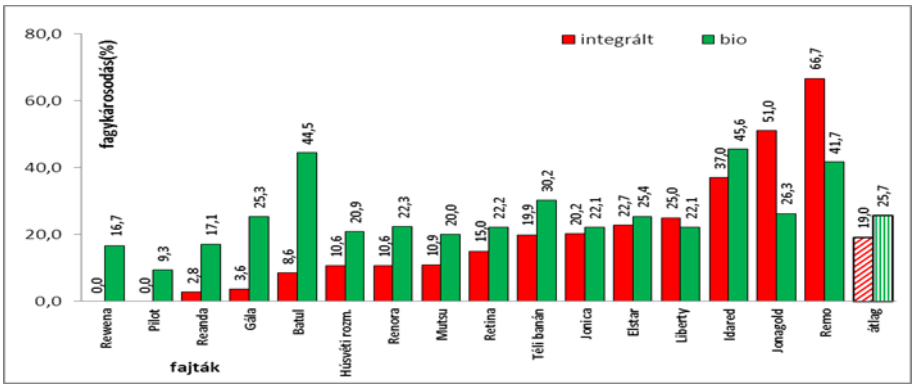

Figure 9. The effect of production technology on frost damage of spears (Debrecen-Pallag, 2009-2010)

It can be seen that production parts shorter than 5 cm were damaged by 13% less in integrated production system compared to organic system.

- **The effect of production technology on frost damage of broaches**

  The effect can be seen in figure 10.

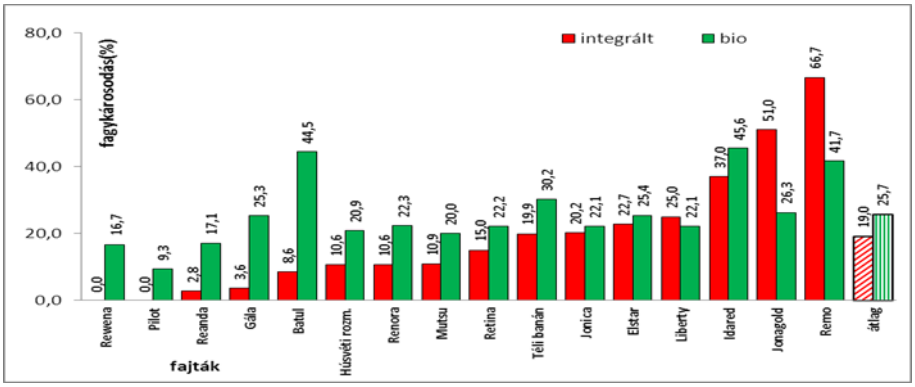

Figure 10. The effect of production technology on frost damage of broaches (Debrecen-Pallag, 2009-2010)

Due to frost damage, mean differences among the two production system are 7 %.

Yield of apple cultivars

The effect of different production system can be seen in figure 11.

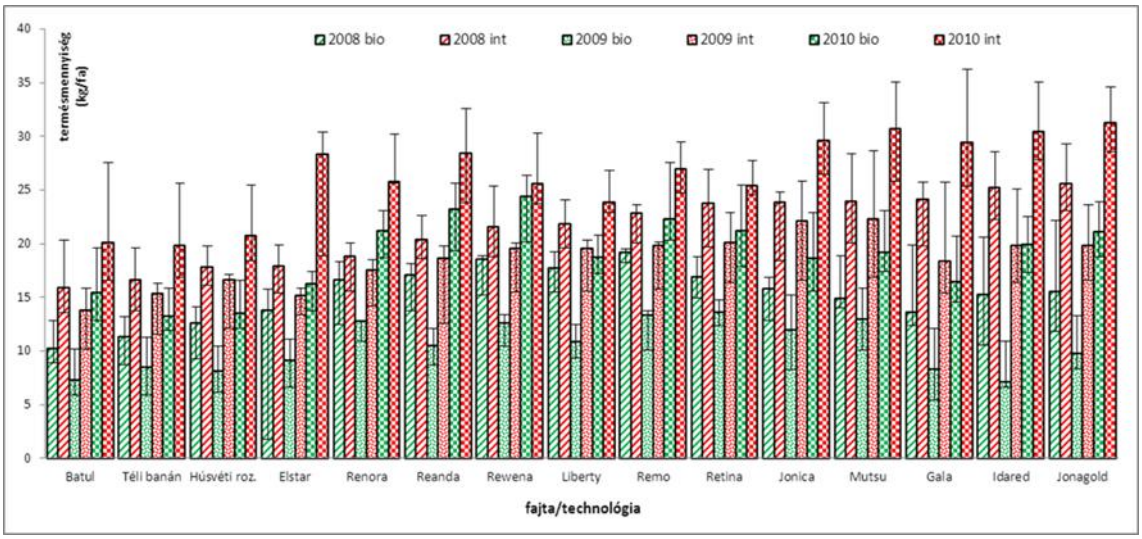

Figure 11. Yield of apple cultivars (Debrecen-Pallag, 2008-2010)

Mean of the three years showed that yield differences were 6 kg/tree independently from cultivars and production system. This means approximately 10 t/ha yield differences.

Plant protection of the orchards

- Infection caused by *Venturia inaequalis* can be seen in figure 12.

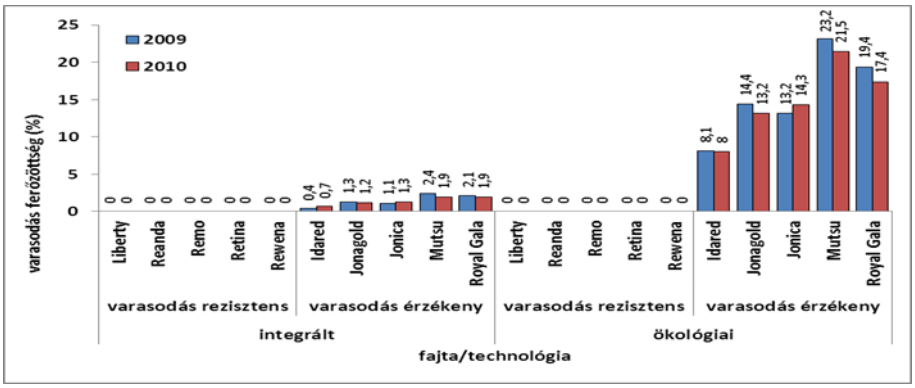

Figure 12. Scab infection on the 14 years old orchard (Debrecen-Pallag, 2009-2010)

The yearly scab infections were different. There were years when the weather was conductive to infection. In the organic production system, source of inoculum (infected fallen leaves, pruned loppins) increased year to year, and disease pressure also increased even in years with less favourably weather conditions.

- Infection caused by codling moth can be seen in figure 13**.**

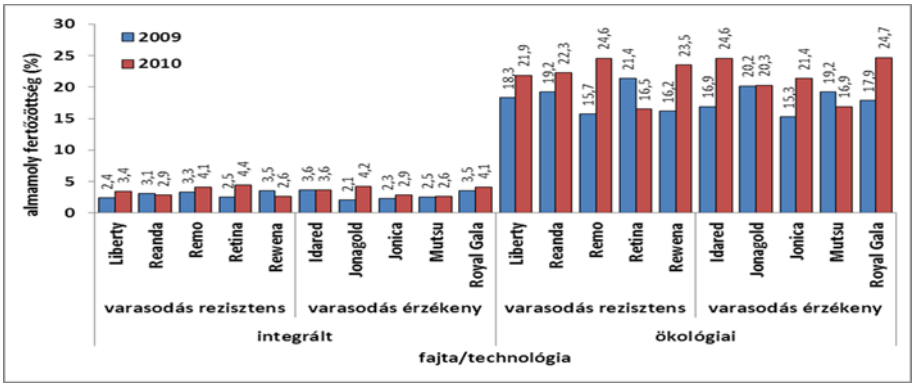

Figure 13. Codling moth infection on the 14 years old orchard (Debrecen-Pallag, 2009-2010)

The organic production systems has several advantages but a large disadvantages can be seen for codling moth damage. Figure shows that control against acdoling mosth is not effective in organic production system. There were no differences of codling moth damag among cultivars. The codling mosth damage was clearly lower in integrated production system compared to organic one.

Comparative organoleptic features and inner contents of apple cultivars

- The organoliptic ratings of flesh firmness of apple cultivars can be seen in figure 14.

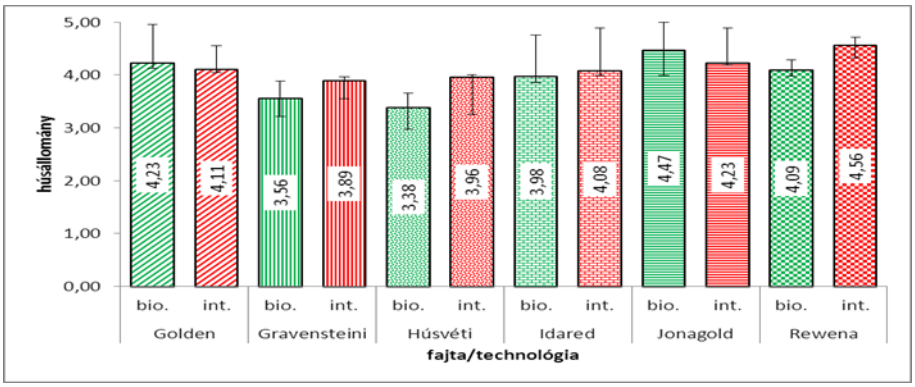

Figure 14. Organoleptic rewiev of flesh firmness of different apple cultivars (Debrecen-Pallag, 2008-2010).

Most apple cultivars were rated with a higer score in the integrated aproduction compared to organic production.

Flesh firmness of apple cultivars

The difference of flesh firmness of apple cultivars can be seen in figure 15.

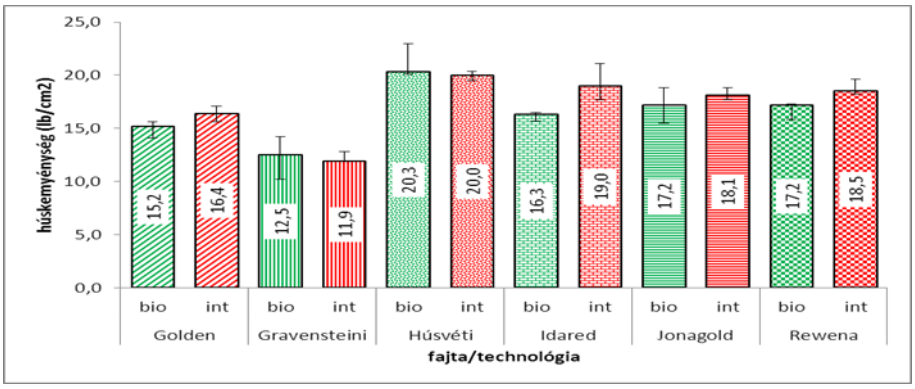

Figure 15. Flesh firmness of apple cultivars (Debrecen-Pallag, 2008-2010).

Among the examined 6 apple cultivars, firmness was larger significantly only for 1 organic cultivar compared to the integrated onces. The other 5 cultivars were firmer in the integrated production system compared to organic one. Only by the cultivar Gravensteini can bee seen statistically difference for the organic production, with 0.6lb/cm^2.

Organoleptic rating of acid/sugar content harmony

The organoleptic rating of acid/sugar harmony of apple cultivars can be seen in figure 16.

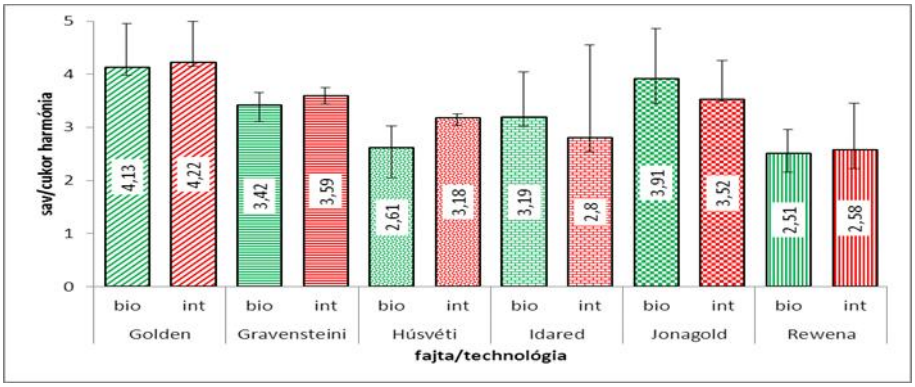

Figure 16. Organoleptic acid/sugar harmony of apple cultivars (Debrecen-Pallag, 2008-2010)

Among the organic produced cultivars, cvs Idared and Jonagold got higher grades. No difference were observed between the two production systems. It needs to note that cultivars showed large differences among years. In favorable years, world-wide known culivars received high grades. such as Golden delicious, Idared, Jonagold, however other cultivars received lower grades at the same time.

Quality index (QI)

The quality index (QI) of apple cultivars can be seen in figure 17.

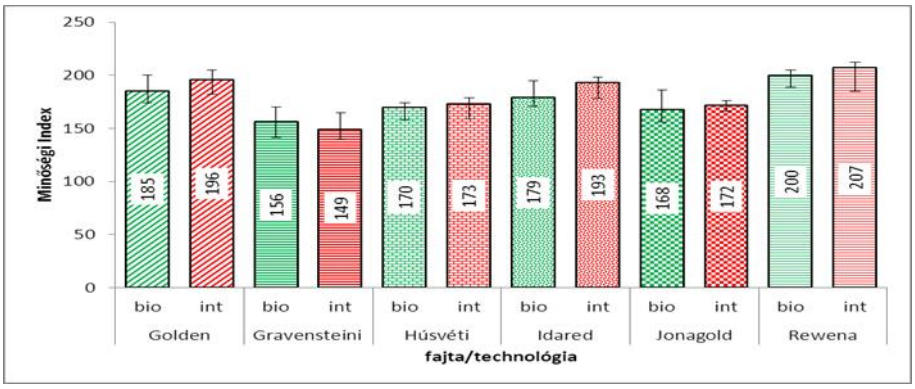

Figure 17. Quality index (QI) of apple cultivars (Debrecen-Pallag, 2008-2010).

Comparing figure 15 and 16, it can can be seen that the simple measurement of high quality index (QI) value disagreed with the customers organoleptic rating.

Customers rate of all organoleptic parameters of cultivars

The customers rate of all parameters of apple cultivars can be seen in figure 18.

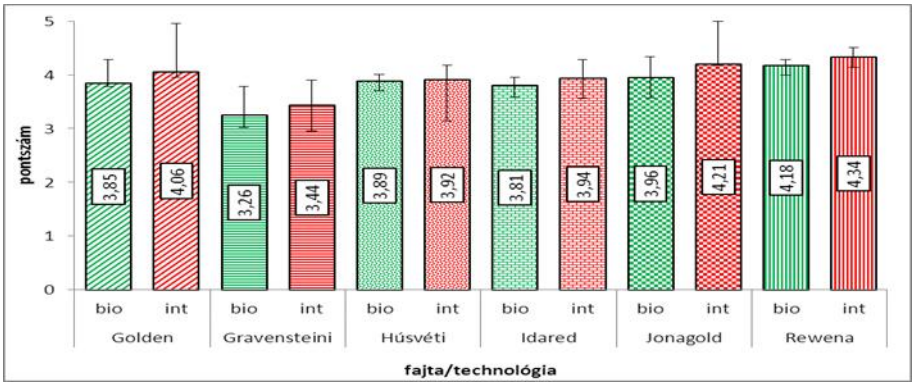

Figure 18. The customers rate of all parameters of apple cultivars (Debrecen-Pallag, 2008-2010)

Summarizing the data, it can be seen that values from integrated production system were more favourable compared to organic production system. Among the examined cultivars, cvs Golden delicious and Jonagold received the highest grades and they received maximum grades in several cases.

Inner contents of apple cultivars

Soulbe solid content of apple cultivars can be seen in figure 19.

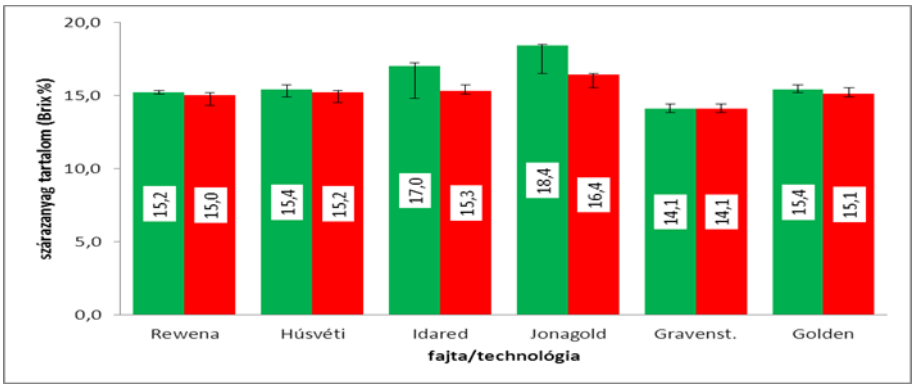

Figure 19. Soluble solid content of apple cultivars (Debrecen-Pallag, 2008-2010)

Summarizing the data, the organically produced apple cultivars had higher soluble solid content than the integrated pairs. That difference can be explaind by the smaller sizes of the organical apple, which can be referred as „concentrated" inner content.

Sugar content of apple cultivars

Sugar content of apple cultivars can be seen in figure 20.

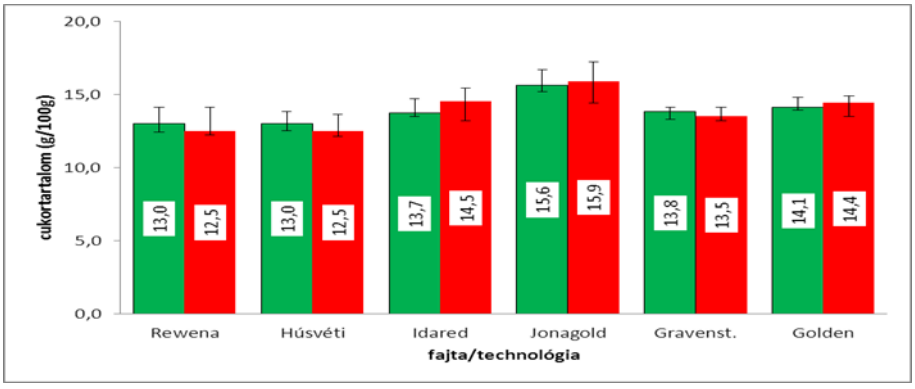

Figure 20. Sugar content of apple cultivars (Debrecen-Pallag, 2008-2010)

In the average data of cultivars, the difference between two production system was imperceptible (0.1%), there isn't tendency related to the difference. In other words, the different production systems has no effect on sugar content of fruitd. Cultivar Jonagold had the highest sugar content in both production systems.

C-vitamin content of apple cultivars

C-vitamin content of apple cultivars can be seen in figure 21.

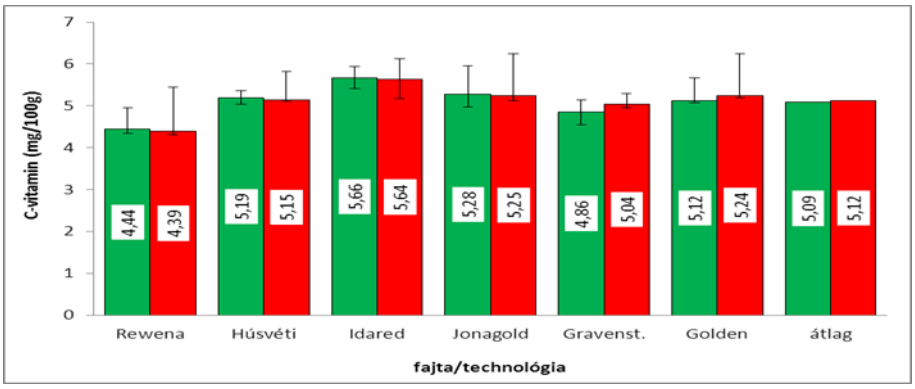

Figure 21. C-vitamin content of apple cultivars (Debrecen-Pallag, 2008-2010)

The difference of C-vitamin content between the two production systems were due to cultivar feature and genetically determined. The highest C-vitamin values were measured for the world-wide known apple (cvs Idared, Jonagold, Golden delicious). The reason could be that fruits are situated more equipartitionally in the crown of integrated production system, therefore they receive more light which result in a higher C-vitamin content of the fruit compared to integrated production system.

Calcium content of apple cultivars

Calcium content of apple cultivars can be seen in figure 22.

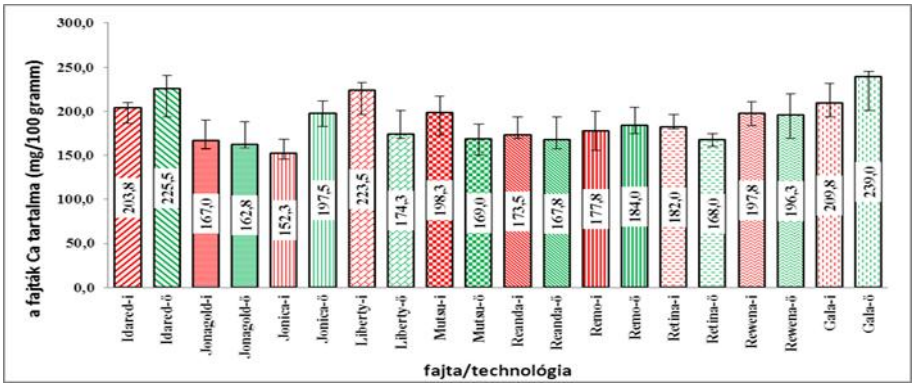

Figure 22. Calcium content of apple cultivars (Debrecen-Pallag, 2008-2010)

Among cultivars, the organically produced cvs. Gala and Idared had the highest calcium content. In the integrated orchard, cv. Liberty had the highest calcium content. The lowest calcium content was measured in cvs. Jonica and Jonagold grown in integrated production system.

5. Summary

The world fruit production growth is greater then the world human population. By now marketing crisis and/or unfavourable overproduction cause great difficulties in fruit production. Conditions for fruit selling are controlled in enviromental friendly produced fruit. This is what the consumers willing to pay.

In our study historical and resistant apple cultivars were compared in integrated and organic fruit production system including performance of vegetative and reproductive ability of apple cultivars as well as quality parameters. Year effect was also analysed with special attention to winter frost damage and plant protection status. The research was performed at Pallag Experimental Station, and trees planted in 1997 using 40 apple cultivars. Trees were grafted on M26 rootstock with 4x1.5 m distances, performed on free spindle crown form.

Our results showed that differences among parameters were associated with conditional and plant protection features of the trees. Integrated production system promoted, while organic production delayed the maintainance and performance of intensive crown forms.

It was also proved that yield safety (yield and good fruit quality) is greater in integrated growing conditions with 30-40% compared to organic growing production.

Winter frost was also greater in organic production compared to integrated production. In case of plant protection, apple scab and codling moth damages were also greater in the organic production system compared to integrated one. However, cultivars showed great differences among each other.

Members of the resistant cultivar group showed ability to grow under less favorable conditions in organic production. Our results clearly showed that research on newer cultivars and on approved plant protection product is one of the most essential tasks for competetive organic apple production.

6. New scientific results

1. We confirmed that the trunk cross section area was larger in organic production with 4-23% and the lateral branches were with 10-50% thicker than integrated production. Inrelation to this the central axes was thinner with 10-30% compared to trees in integrated production system.

2. We confirm that the numbers of lateral branches were bigger with 10-100% and the lateral branches were thinner with 10-50% in the tree crown in integrated production compared to organic production wich contributed to a favourable crown form.

3. We stated that the frost damage of short fruit bearing shoots (1-5 cm) and of longer fruiting shoots (6-20 cm) were larger 35% and 7%, respectively, in organic production system compared to trees in integrated. On the other hand, frost damage of top terminal buds were more considerable in integrated production.

4. We stated that degree of pruning influence growth characteristics of the trees with larger extend compared to the production systems. In organic production, only stronger pruning can result the same favourable growth characteristics for most cultivars compared to integrated. In a few cultivars there is no different effect among pruning methods.

5. We stated that the scab resistant apple cultivars showed no scab infection either in young or older ages. The other 2 apple cultivar groups infection was lower on younger trees but as they ages the scab damages become more considerable. We stated that the degree of Codling moth damage were larger organic production system compared to integrated independently from cultivars.

7. Practically useful results

1. In organic production Zahn's central axes dominancy can be performed hardly while it is anessential criterium for intensive crown form.

2. We stated that integrated production could give the option for the use of more intensive crown forms. However in organic production more extensive and larger crown forms need to be used compared to integrated production.

3. We stated that both quantity and quality of yield were lower with an average of 30% in organic production system compared to integrated production system due to disadvantages of conditional status and/or plant protection efficacy.

4. According to our results the smallest differences in yield were observed in resistant cultivars (with the exception of cv. Retina) in both integrated and organic production system wich verify the suitability of these cultivars for organic growing. On the other hand historical cultivars produced lower yield compared to the resistant onces but larger yield compared to worldwide used cultivars. Worldwide produced 40% less yield in organic production system compared to other 2 cultivar groups.

5. Our results confirmed that in organic production system efficient control against apple scab and codling moth can be reached only on resistant cultivars.

8. PUBLICATION LIST IN THE THEME OF PHD THESIS

Candidate: Péter Dremák
Neptun ID: Y4Q0D4
Doctoral School: Hankóczy Jenő Doctoral School of Crop Production, Horticulture and Food Sciences
MTMT ID: 10028951

List of publications related to the dissertation

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

1. **Dremák P.**: Fagykárosodás az ökológiai és integrált technológiájú almaültetvényekben. *"Klíma-21" Füz. 64*, 27-31, 2011. ISSN: 1218-5329.

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Total IF of journals (all publications): 1,396
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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.

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