CORVINUS UNIVERSITY OF BUDAPEST

Thesis of PhD Dissertation

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The effect, role and importance of grafting in musk- and watermelon cultivation in Hungary

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1. INTRODUCTION, GOALS

Cultivation of melon species has great traditions in Hungary. Grafting is considered to be one of the most modern and innovative techniques of the past few years. Farmers and researchers both often ask why it is necessary to use grafted plants. One advantage is that it enables monocultural production. Some farmers plant melon on the same land for 5-6 consecutive years. Another reason for using grafted melons is that planting can be started earlier, thus the fruits are ready to be picked 4-5 days before those of non-grafted ones. The yields are also higher in case of grafted cultures. Perhaps the most important advantage of using grafted plants is that the cultivation risks become lower and the plants are more resistant to soil-borne diseases and pests.

The total size of the melon producing areas varies from year to year. In 2011, **muskmelon** (*Cucumis melo* L.) was cultivated on 510 ha; of which only around 40 ha was grafted plantation. In 2006 and 2007 grafted muskmelons were grown on 1000 ha. In forcing, the usage of grafted plants is getting more and more important because of nematodes living in the soil of glasshouses. There are only initial attempts for grafting muskmelons, unlike in case of watermelons, where grafted plants are used in a higher percentage.

The **watermelon** (*Citrullus lanatus* [Thumb] Mansfeeld) producing area is getting smaller by each year as well, although it is still the 3rd vegetable grown in largest scale. According to data of Fruitveb, watermelon was cultivated on 4800 ha in Hungary, but in the previous years this area was much bigger. Even so, the percentage of grafted plants increased, as in 2010, the size of grafted plantations was approx. 1500 ha, while in 2012 it reached almost 2000 ha.

By 2013, a close to 10% increase of the watermelon producing area is predicted, while the ratio of grafted plantations grows as well. Experts say that the same change is likely to happen in case of muskmelon production too.

According to consumer opinions, sometimes grafted watermelons have a characteristic squash taste, which they blame on grafting. In my opinion, the taste is not the result of grafting. The difference between the fertilization of grafted and non-grafted plants should be put into focus, as melons grafted onto squash rootstocks need less nitrate and more potassium than non-grafted ones.

Muskmelons and watermelons have important roles in today's modern and health conscious diets, especially if they become more nutrient rich due to grafting. Many farmers are considering using grafted plants because of the extreme weather conditions of Hungary.

Since rootstocks have different characteristics, choosing the right type is important. Watermelons are grafted onto interspecific or *Lagenaria* rootstocks. Farmers decide which one to use based on different factors: cultivation technology, time of planting, type of scion and soil conditions. In case of muskmelons, only interspecific rootstocks are used.

Some producers are against planting grafted seedlings because of their higher price. Although the costs are higher, the yields are better, which explains why grafting is still considered to be a good solution. One thing has to be kept in the focus: the seasons are never the same. In order to be able to find the optimal scion-rootstock combination, the producer has to have some important information about the rootstock, e. g. root type, resistance, vigor, effect on fruit ripening etc.

In my opinion (and that of many farmers), grafting is a long-term solution in case of both watermelons and muskmelons.

The aims of my water- and muskmelon grafting field experiments were the following:

- Studying the effect of the different rootstocks on the scions.
- Finding the scion-rootstock water- and muskmelon combinations optimal for the production area of Hungary (Békés county), where the most intensive cultivation takes place.
- Studying the effect of the different scion-rootstock combinations on the yields, vigor and foliage regeneration of water- and muskmelons.
- By laboratory analysis, determining the refraction of grafted and non-grafted water- and muskmelons; and the dry matter content, acid and sugar content, the antioxidant capacity and the total polyphenol content of both the grafted and non-grafted muskmelons.
- Sensory analysis of fruits of grafted and non-grafted muskmelon plants.
- Preparing economic models on grafted and non-grafted melon production.

2. MATERIAL AND METHODS

2.1. Material of the grafting experiments

The muskmelon (*Cucumis melo* L.) grafting experiments were carried out between 2006 and 2011 and included the following varieties:

- 4 *Galia* type (green flesh) varieties: *Capri, Edecos, London, Siglo*
- 2 cantaloupe type: *Centro, Donatello*,
- 2 other varieties: *Gordes, Muskotály*,
- 6 interspecific squash rootstocks: *Beton, RS 841, Routpower, Strongtosa, Kazako, Shintoza Camelforce*.

The varieties used in the watermelon (*Citrullus lanatus* [Thumb] Mansfeeld) grafting experiments (2010 and 2011) are:

- 5 container sized varieties: *Crimstar*, *Sprinter*, *Early Beauty*, *Crispeed,*
- 6 icebox varieties: *Tiger Baby*, *Susy*, *ZKI 10-55*, *Boxi*, *Esmeralda*, *WDL 9707,*
- 3 interspecific varieties: *Nimbus*, *Titán*, *Carnivor,*
- 3 *Lagenaria* rootstock varieties: *Argentario*, *Macis*, *Nun 3001.*

Tables 1. and **2.** show the sawing dates and the spacing of the water- and muskmelon scions and rootstocks and that of the varieties used as control.

One cotyledon grafting was used in the experiment. In this method, one of the two cotyledons of the rootstock is removed by a 45° cut, while the scion is cut under the cotyledons 45° as well, then the two surfaces are gently joined and finally fixed with a special clip. The grafted seedlings are then placed in a chamber with high temperature and humidity (around 95%).

Table 1. Propagation data of the muskmelon experiments

Treatment	Muskmelon 2006			Muskmelon 2007			Muskmelon 2008		
	sawing	grafting	planting	sawing	grafting	planting	sawing	grafting	planting
control	10th April		10th May	23rd March		20th April	14th March		20th April
rootstock	10th April	24th April		23rd March	3rd April		23rd March	4th April	
scion	31st March			13rd March			14th March		
spacing	300+80 x 100 cm (0,52 plant/m^2)			160 x 120 (52 plant/m^2)					

	Muskmelon 2009			Muskmelon 2011		
	sawing	grafting	planting	sawing	grafting	planting
control	4th March		15th April	21st March		6th May
rootstock	14th March	25th March		4th April	24th April	
scion	4th March			21st March		
spacing	230 X 100 cm (0,43 plant/m^2)			non-grafted: 230x100cm (0,43 plant/m^2)		
				grafted: 230x50 cm (0,87 plant/m^2)		

In 2006, 2007 and 2008 the muskmelon experiment was conducted in 2 repeats (with 10 plants in one repeat), while in 2009, 2010 and 2011 the number of repeats were 4 (with 5 plants in each).

Table 2. Propagation data of the watermelon experiments

Treatment	Watermelon 2010			Watermelon 2011		
	sawing	grafting	planting	sawing	grafting	planting
control	16th March		30th April	29th March		20th April
rootstock	16th March	13th April		29th March	6th April	
scion	10th March			18th March		

Both years, the spacing of non-grafted watermelon seedlings was 2.7 x 0.5 m (0.74 plant/m^2), while that of the grafted ones was 2.7 x 1 m (0.34 plant/m^2).

In 2010 the experiment was carried out in two repeats (with 10 plant in each repeat), but in 2011 it was reduced to 2 (with 20 plants in each repeat), due to the high number of plant.

2.2. Measured parameters

On each location (*muskmelon*: Kiskunfélegyháza, Medgyesbodzás, Dombegyház; *watermelon:* Medgyesegyháza), in case of both species the yield and the foliage regeneration were measured. In the laboratory, the refraction of both types of melons and the dry matter, carbohydrate and acid content, as well as the antioxidant and total polyphenol content of muskmelons were determined.

2.2.1. Yield and morphology

After sorting and counting, the yield per hectare and per plant, as well as the average weight was measured by digital scale, in case of both species.

The foliage regeneration and vigor was determined on a 1 to 5 scale (1: lowest, 5: highest regeneration and vigor).

2.2.2. Laboratory analysis

For the purposes of laboratory analysis, 4-5 similarly ripened fruits were picked from the grafted plants. Homogenization was done on the day or on the following day of picking. Refraction was determined at the same time.

Homogenized watermelon and muskmelon samples were used for the following analysis:

Refraction

The refraction of muskmelon samples was determined in each year, while in case of watermelons, only in 2011. Digital manual refractometer (PAL-1, ATAGO) was used, and the results are given in *Brix* °.

Dry matter content

In each year, the total dry matter content of muskmelon samples were measured according to the MSZ 2429-1980 standard.

Carbohydrate content

In 2009 and 2011, the total and reducing sugar content of the muskmelon samples was determined by applying the *Luff-Schorl method.*

Acid content

The acid content of muskmelons was measured in 2009 and 2011, by following the MSZ 3619-1983 standard. The results are given in percentage.

Antioxidant capacity

Antioxidant capacity of the muskmelon fruit samples was determined each year, by the modified *Benzie and Strain* (1966) *method.*

Total polyphenol content

Total polyphenol content, which closely connected to antioxidant capacity, is measured by using *Folin-Ciocalteu* reagent (λ = 760 nm) (Singleton and Rossi, 1965) and

spectrophotometer. Polyphenols are secondary metabolites that have an important role in the defense system of the plants.

Sensory analysis

It is important to evaluate consumer satisfaction in case of grafted melons. The scale of this study did not allow a representative preference study with hundreds of consumers, thus sensory evaluation and analysis was conducted in a group of experienced testers, in 2010 and 2011. For the purpose of the sensory evaluation, one scoring method was chosen from the 20 types of ISO standards. The minimum score was 1, the maximum 10. The following characteristics were studied: succulence, flesh consistency, aftertaste, taste, aroma intensity and flesh color.

Statistical evaluation

Results of the sensory analysis were evaluated by one-way analysis of variance (*ANOVA*). For the evaluation, the *ProfiSens* sensory software (developed by the Sensory Laboratory of CUB and the Budapest University of Technology and Economics) was used.

For the evaluation of the data of water- and muskmelon field trials and laboratory analysis (2009 and 2011) *SPSS* statistical package program was used.

3. RESULTS AND DISCUSSION

3.1. Muskmelon yield results

Average yields of grafted muskmelon plants were higher than that of the non-grafted ones in each experimental year. This result correlates with the data found in international publications.

Two varieties *Muskotály* and *Siglo* and their grafted combinations were included in the trial only in one year (*Muskotály* – 2006, *Siglo* – 2007). *Beton* and *Shintosa* proved to be the most optimal rootstocks of *Muskotály*, while for *Siglo*, *Beton* and *RS 84*1 had the most positive effect.

In case of other varieties, which were included in field trials for multiple years, weather conditions of the different years and the locations of the trials have great influence on the results. This was proven statistically ($p<0.05$) in 2009 and 2011.

Grafted *Gordes* and *Capri* had the highest yields in 2007. In case of grafted *Centro*, 2007 and 2009 resulted in the best yields per plant. The most optimal rootstocks are proved to be *Strongtosa*, *Beton*, *RS 841* and *Routpower* (**Figure 1.**).

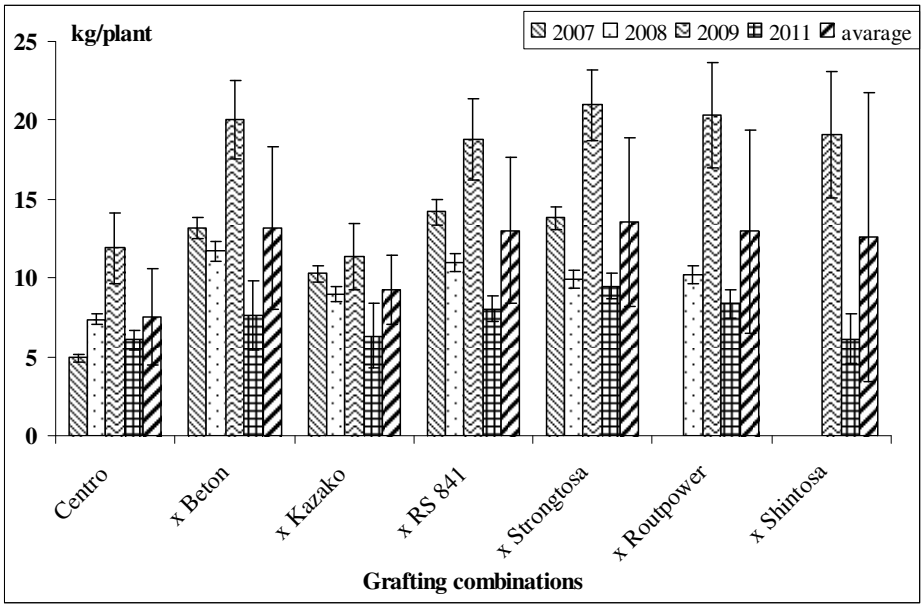

Figure 1. Yield per plant of the scion *Centro* and its grafting combinations (2007, 2008, 2009 and 2011)

From the three experimental years (2008, 2009 and 2011), *Donatello* had the highest yields per plant in 2008 and 2009. Rootstocks *Routpower, Beton* and *Strongtosa* were the best. The highest amount was picked from the *Galia* type *London* and *Edecos* in 2009. *Beton* and *Strongtosa* are good rootstocks of both varieties.

RS 841 is also a recommended rootstock of *Edecos*. From the yield point of view, squash rootstocks *Beton*, *RS 841, Strongtosa* and *Routpower* can all very well be used for grafting most examined scions.

The positive effect on the yield was not noticeable when the yields per plant are conversed to yield per hectare. A significant growth would only have been detected, if the grafted plants would have yielded twice than the non-grafted ones.

No growth in the yield per hectare value was detected in case of *Edecos, Beton, Centro, Muskotály* and *Donatello* grafted on any rootstock varieties. In case of *Capri*, *Siglo* and *Gordes*, the rootstock *Strongtosa* had obvious positive effect. Results of the trials proved that varieties *Muskotály* and *Capri* are not recommended for open field cultivation, which could be explained by the not very vigorous foliage and thin skin.

When measuring average weight, both positive and negative effects of grafting were detected, which correlated with the data found in international literature. It has been concluded, that weather conditions highly influence fruit weight.

One result was especially interesting. The *Siglo x Kazako* combination had the lowest yield compared to other rootstocks, while the average weight was the highest. This means that although the yield is low in case of this grafting combination, the fruits are bigger.

Table 3. contains the scion-rootstock combinations recommended based on yield results.

Table 3. The recommended scion-rootstock combinations based on yield results

SCION/ROOTSTOCK	*Beton*	*Kazako*	*RS 841*	*Strongtosa*	*Routpower*	*Shintosa*
Capri		X	X	X	X	
Edecos	X	X	X	X	X	
London	X	X	X	X	X	
Siglo (1 year)	X	X	X	X	X	X
Centro	X	X	X	X	X	X
Donatello	X	X	X	X	X	X
Gordes		X	X	X		X
Muskotály (1 year)	X		X			X

3.2. Laboratory analysis of muskmelon

3.2.1. Refraction

In case of certain varieties, grafting caused lower *Brix* ° in both years (for example: *Gordes* and combinations, with the exception of *Gordes x RS 841* in 2006).

Grafting resulted in lower water soluble dry matter content in 2006 in *Muskotály*. According to average data of all experimental years, *Shintosa* had the same effect on most scions, just like it is described in international research reports.

3.2.2. Dry matter content

Dry matter content evaluation led to the conclusion that weather conditions have an important role.

In case of *Capri*, in 2006 each grafted combination had lower dry matter content than the non-grafted one, unlike in 2007 and 2008, when the opposite was measured.

In the third experimental year (2008), each grafted muskmelon (with the exception of *Donatello x Kazako*) had higher dry matter content than the non-grafted plants. In 2009 and 2011, with the exception of *Centro* combinations, the dry matter content of the fruits of grafted plants was lower.

3.2.3. Carbohydrates

The effect of weather conditions did not show in reducing sugar content analysis, unlike when the sucrose content (which is responsible for the sweet taste of the fruit) was determined.

In case of *London*, the fruits of grafted plants had lower reducing sugar levels than the non-grafted ones in both years (2009 and 2011).

In 2009, each rootstock (except *Routpower*) had a negative effect on the invert sugar content of the green-fleshed *Galia* type scions (*Edecos*, *London*); while in 2011 the invert sugar level grew in case of all rootstocks. These contradictory data can be explained by the more optimal moisture content of the soil due to heavy rains (133 mm) in July 2011. The variety type was another important factor in the forming of sugar content.

In 2011, the green-fleshed *Galia* type *Edecos* and *London* grafted on each rootstock had better results than the non-grafted ones, unlike in case of the yellow-fleshed cantaloupe types (except: *Centro x Kazako, Centro x RS 841*), where the grafted plants had lower values than the non-grafted ones.

Results showed that *Donatello,* grafted on any rootstock and under any weather conditions, had lower sugar content, than the control. Researchers say that grafting does not have a negative effect on the sugar content of the fruits, but due to results of this experiment, it can be seen that in case of some varieties, the sugar content is lower in the grafted plants, than in the non-grafted.

It can be concluded, that in most cases there is no connection between the sugar content and the refraction.

3.2.4. Acid content

In 2011, the effect of the growing season's weather was most significant in case of the variety *Centro*, which had higher acid content when grafted, unlike in 2009, when each rootstock had a negative effect on acid level. The same was found in case of some other combinations and their non-grafted controls (*Edecos x Beton*, 2009; *Edecos x Strongtosa*, 2009; *London x Beton*, 2009).

3.2.5. Antioxidant capacity

In case of *Muskotály* and *Capri* (**Figure 2.**), based on the average of the measured data, each rootstock had a positive effect on the antioxidant level.

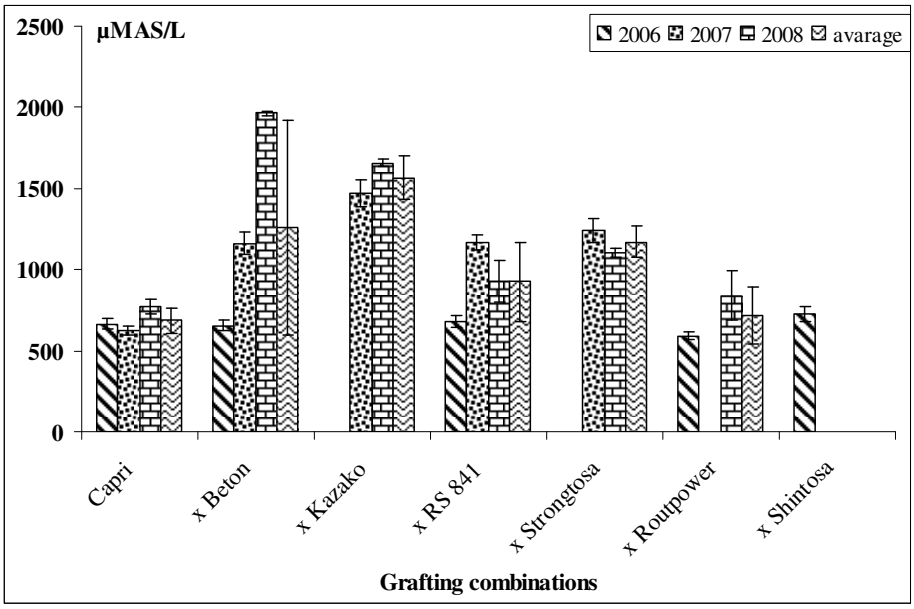

Figure 2. Antioxidant capacity of the variety *Capri* and its grafted combinations (2006, 2007 and 2008)

Some rootstocks had the same effect on certain scions, but the most significant positive change was caused by *Kazako*, *RS 841* and *Beton*.

3.2.6. Total polyphenol content

Grafting the yellow fleshed cantaloupe type *Centro* on any rootstock variety caused higher polyphenol levels.

In case of *Muskotály*, *Gordes* and *Donatello* (**Figure 3.**), the fruits of grafted plants had lower polyphenol content than the control (non-grafted) ones. This characteristic could cohere with the fact that non-grafted plants are less tolerant to stresses (e. g. abiotic stresses) than grafted plants.

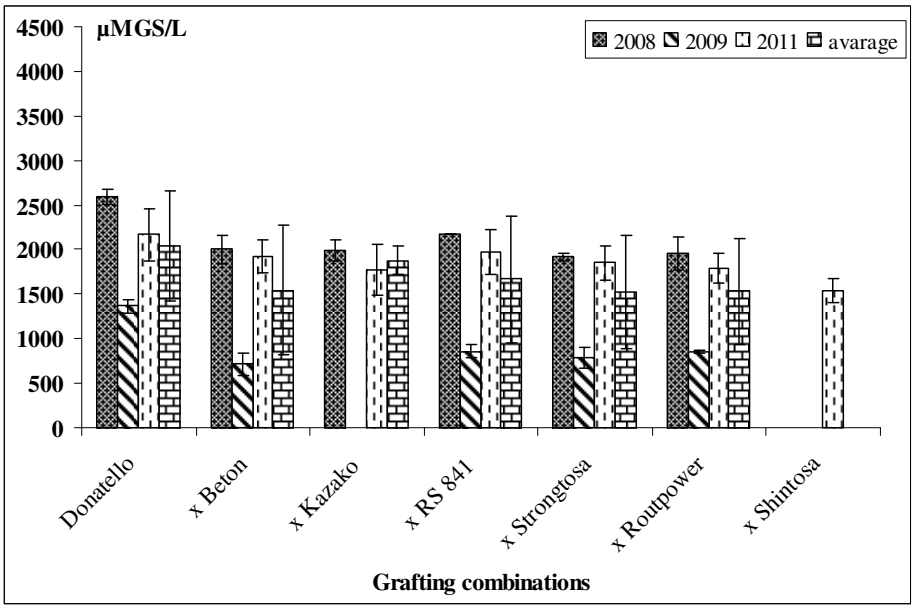

Figure 3. The total polyphenol content of *Donatello* and its combinations (2008, 2009 and 2011)

Based on the laboratory analysis results, the scion-rootstock muskmelon combinations showed on **Table 4.** are recommended for cultivation

Table 5. shows the yields and results of the laboratory analysis. Each case the non-grafted variety is compared with the grafted combinations. "–" means that better results were found in case of the non-grafted plants, and "+", when grafting caused higher values/levels. If there were no significant difference detected between non-grafted and grafted plants, an "x" mark can be seen in the table.

Table 4. Recommended scion-rootstock muskmelon combinations (based on laboratory analysis)

SCION/ROOTSTOCK	*Beton*	*Kazako*	*RS 841*	*Strongtosa*	*Routpower*	*Shintosa*
Capri	X	X	X	X		
Edecos		X	X		X	X
London		X				X
Siglo (1 year)		X				
Centro	X	X	X			
Donatello			X			
Gordes			X			
Muskotály (1 year)						

Table 5. Summary of the results of the field experiment and laboratory analysis of grafted and non-grafted muskmelons

GRAFTING COMBINATIONS	Yield/plant	Yield/hectare	Average fruit weight	Refraction	Dry matter content	Reducing sugar	Invert sugar	Total sugar	Acid content	Antioxidant capacity	Total polyphenol
Capri											
x Beton	- / + / +	- / + / -	+ / + / +	- / + / +	- / + / +					- / + / +	+ / + / +
xKazako	+ / +	+ / -	+ / +	+ / +	+ / +					+ / +	+ / +
xRS 841	+ / + / +	- / + / -	- / + / +	- / + / +	- / + / +					+ / + / +	+ / + / +
x Strongtosa	+ / +	+ / +	+ / +	+ / +	+ / +					+ / +	+ / -
xRoutpower	+ / +	- / -	+ / +	- / +	- / +					- / +	- / -
x Shintosa	+	- /	-	-	-					+	+
Edecos											
x Beton	+ / +	- / -	+ / +	- / -	- / -	+ / +	- / +	- / +	x / +	- / -	+ / -
x Kazako	+	-	+	+	-	-	+	+	+	+	-
x RS 841	+ / +	- / -	+ / +	+ / +	- / -	+ / -	- / +	+ / +	- / +	- / +	- / +
x Strongtosa	+ / +	- / -	+ / +	- / -	- / -	+ / +	- / +	- / +	x / +	- / +	+ / -
x Routpower	+ / +	- / -	+ / +	+ / +	+ / -	+ / +	+ / +	+ / +	+ / +	- / +	+ / -
x Shintosa	+	-	+	+	-	+	+	+	+	+	+
London											
x Beton	+ / + / +	+ / - / -	+ / + / +	+ / - / -	+ / - / -	- / -	- / +	- / +	x / +	+ / - / +	- / - / -
x Kazako	+ / + / +	- / - / -	+ / + / +	+ / - / +	+ / - / -	- / -	- / +	- / +	x / +	+ / + / +	+ / - / +
x RS 841	+ / + / +	+ / - / -	+ / + / +	+ / - / +	+ / + / -	- / -	- / +	- / +	+ / +	- / - / +	+ / - / -
x Strongtosa	+ / + / +	+ / - / -	+ / + / +	+ / + / +	+ / - / +	- / -	- / +	- / +	x / +	- / - / +	- / - / -
x Routpower	+ / + / +	- / - / -	+ / + / +	+ / + / +	+ / - / -	- / -	- / +	- / +	+ / x	- / - / +	- / - / -
x Shintosa	+	-	+	-	-	-	+	+	+	+	+
Siglo											
x Beton	+	+	+	-	-					+	-
x Kazako	+	+	+	+	+					+	+
x RS 841	+	+	+	-	-					-	-
x Strongtosa	+	+	+	-	-					-	-
Centro											
x Beton	+ / + / + / +	+ / - / - / -	+ / + / + / +	- / + / - / +	- / + / - / +	- / -	+ / +	+ / -	- / +	- / + / - / +	- / + / - / +
x Kazako	+ / + / - / +	+ / - / - / -	+ / + / + / +	+ / + / + / +	+ / + / - / +	+ / +	+ / +	+ / +	- / +	+ / + / - / -	+ / - / - / +
x RS 841	+ / + / + / +	+ / - / - / -	+ / + / + / +	+ / + / - / +	- / + / - / +	+ / -	+ / +	+ / +	- / +	- / + / - / -	- / + / - / +
x Strongtosa	+ / + / + / +	+ / - / - / -	+ / + / + / +	+ / + / + / +	- / + / - / +	+ / +	+ / -	+ / -	- / +	- / + / - / -	- / - / - / +
x Routpower	+ / + / +	- / - / -	+ / + / +	+ / - / +	+ / - / +	+ / -	+ / -	+ / -	- / +	+ / - / -	- / - / +
x Shintosa	+ / +	- / -	+ / -	+	+	-	-	-	+	-	+
Donatello											
x Beton	+ / + / +	- / - / -	+ / + / +	+ / - / -	+ / - / -	- / -	- / -	- / -	+ / +	+ / - / +	- / - / -
x Kazako	+ / +	- / -	+ / -	- / +	- / -	+ / +	-	-	+	- / +	- / -
x RS 841	+ / + / +	- / - / -	+ / + / +	+ / - / +	+ / - / +	+ / -	- / -	- / -	+ / +	- / + / +	- / - / -
x Strongtosa	+ / + / +	- / - / -	+ / + / +	+ / - / -	+ / - / -	+ / +	- / -	- / -	+ / +	- / - / +	- / - / -
x Routpower	+ / + / +	- / - / -	+ / + / +	+ / - / -	+ / - / -	+ / -	- / -	- / -	+ / +	- / - / -	- / - / -
x Shintosa	+	-	+	-	-	-	-	-	x	-	-
Gordes											
x Beton	- / +	- / +	+ / +	- / -	- / -					- / -	- / -
x Kazako	+	-	+	-	-					+	-
x RS 841	+ / +	- / +	+ / +	+ / -	+ / -					- / -	- / -
x Strongtosa	+	+	+	-	-					+	-
x Routpower	-	-	+	-	-					-	-
x Shintosa	+	-	+	-	-					-	-
Muskotály											
x Beton	+	-	+	-	-					+	-
x RS 841	+	-	+	-	-					+	-
x Routpower	-	-	-	-	-					+	-
x Shintosa	+	-	-	-	-					+	-

3.3. Watermelon morphology and yield results

3.3.1. Vigor of the watermelon plants

Result of the field experiment showed that grafted watermelon plants can be characterized with stronger vigor than non-grafted ones. Though, no significant difference was detected between the effect on plant vigor of interspecific and *Lagenaria* type rootstocks.

Certain watermelon scions performed better on *Lagenaria* rootstock (*Crimstar* x *Argentario*; *Crimstar* x *Macis*), and some showed better results on interspecific rootstock (*Lentus* x *Shintosa*; *Esmeralda* x *Shintosa*).

3.3.2. Watermelon yield results

Measuring yields per plant showed that most grafted watermelons have higher yield (which international researches also confirm). In many cases grafted plants had 2 or 3 times higher yields, than the non-grafted ones. Just like during the evaluation of results of the muskmelon experiment, watermelon yields per plant have also been conversed to yield per hectare, after which it had been confirmed, that with the exception of 2-3 varieties (*Boxi, Crimstar, ZKI 10-55*), grafting had a positive effect on not only the yield per plant, but on the yield per hectare value as well.

The same positive effect was detected in all cases when the average fruit weight was measured. Fruits of the container sized *Crispeed* and the icebox type *ZKI 10-55* all became smaller due to grafting.

In 2011, each interspecific type rootstocks resulted in lower fruit weight. Those combinations, that have been included in the experiment in both years (2010 and 2011), have all had bigger fruits in the second year (2011).

3.3.3. Fruit size distribution

The grafted and non-grafted container sized watermelons all had fruits below 6 kg, which could be caused by the weather. In 2011, most icebox type watermelons had fruits weighing more than 5.5 kg, which falls into the container size category (**Figure 4.**). This phenomenon is most likely to be the effect of rootstocks.

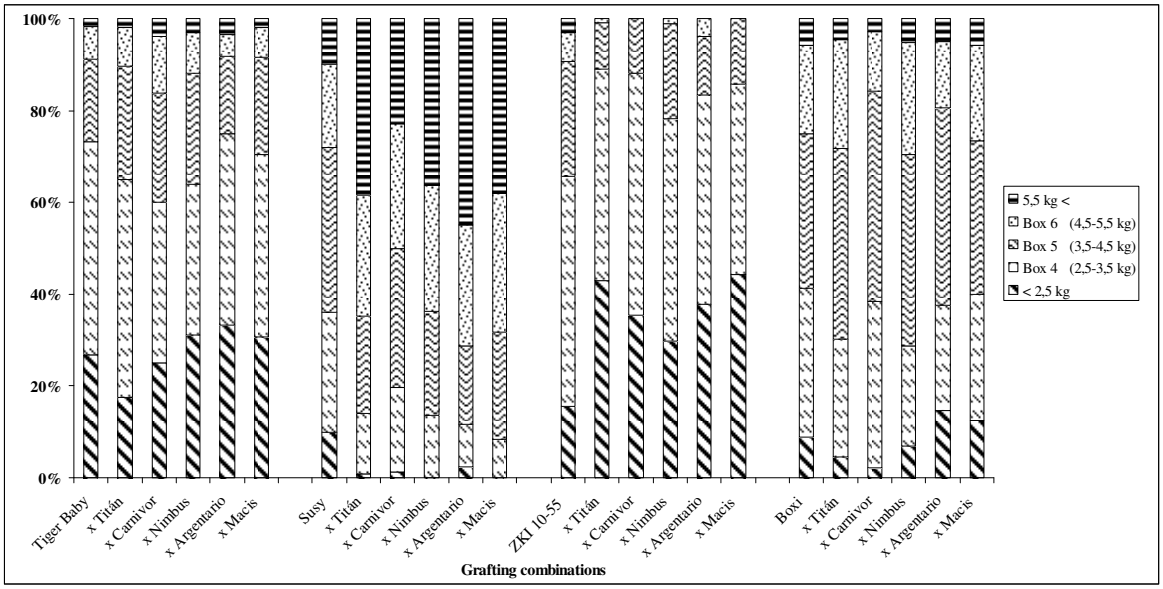

Figure 4. Fruit size distribution of container sized watermelon varieties and their grafted combinations (2010)

3.3.4. Refraction

Some rootstock had positive, some had negative effect on refraction. In case of certain varieties (*Early Beauty*, *Boxi*, *WDL 9707* and *Crispeed*), most grafted plants had higher refraction, than the non-grafted ones. In case of *Sprinter*, grafted combinations had lower *Brix*° than the non-grafted plants.

3.3.5. Foliage regeneration

In 2011, foliage regeneration of those plants was better, which have been grafted onto *Lagenaria* type rootstocks. Some varieties (e. g. *Crispeed*) had better foliage regeneration, if they were not grafted.

3.3.6. Sensory analysis

Contrary to belief, sensory analysis proved that the fruit taste of grafted plants it not always worse than that of the non-grafted ones. More than one factor affects taste, for example: rootstock-scion combination, cultivation technology and fertilization. In my opinion, depending on weather conditions, grafted plants need more potassium, but less nitrogen than the non-grafted plants.

3.3.7. Economic evaluation

Economic evaluation verified that using grafted muskmelon and watermelon for growing has higher costs than using non-grafted plants. The difference is due to the higher price of the grafted seedlings. Safer cultivation and yields compensate for the higher cost. **Table 6.** summarizes the result of the watermelon experiments and analysis. Each case the non-grafted variety is compared with the grafted combinations. "–" means that better results were found in case of the non-grafted plants, and "+", when grafting caused higher values/levels. If there were no significant difference detected between non-grafted and grafted plants, an "x" mark can be seen in the table.

Table 6. Summary of the results of the field experiment and laboratory analysis of grafted and non-grafted watermelons

GRAFTING COMBINATIONS	Yield/plant	Yield/hectare	Average fruit weight	Vigor	Foliage regeneration	Refraction
Lonci						
x Titán	+ / +	+ / +	+ / -	+ / +	x	-
x Carnivor	+ / +	+ / -	+ / +	+ / +	+	+
x Nimbus	+ / +	+ / -	+ / +	+ / +	+	+
x Argentario	+ / +	+ / -	+ / +	+ / +	+	-
x Macis	+	+	+	+		
x Nun 3001	+	-	+	+	+	-
Sprinter						
x Titán	+ / +	+ / +	+ / -	+ / +	-	-
x Carnivor	+ / +	+ / x	+ / -	+ / +	-	-
x Nimbus	+ / +	+ / -	+ / -	+ / +	-	-
x Argentario	+ / +	+ / -	+ / +	+ / +	+	-
x Macis	+	+	+	+		
x Nun 3001	+	-	-	+	+	-
Early Beauty						
x Titán	+ / +	+ / +	+ / -	+ / +	-	+
x Carnivor	+ / +	+ / +	+ / -	+ / +	-	+
x Nimbus	+ / +	+ / +	+ / -	+ / +	-	+
x Argentario	+ / +	+ / +	+ / -	+ / +	+	+
x Macis	+	+	+	+	+	
x Nun 3001	+	+	+	+		+
Crimstar						
x Titán	+	-	+	+		
xCarnivor	+	-	+	+		
x Nimbus	+	-	+	-		
x Argentario	+	+	+	+		
x Macis	+	-	+	+		
Crispeed						
x Titán	-	-	-	+	-	+
xCarnivor	+	-	-	+	-	+
x Nimbus	+	-	-	+	-	+
x Argentario	+	-	-	+	-	+
x Nun 3001	+	-	-	+	-	+

Based on results of the 2010 and 2011 filed experiments, the combinations of container sized watermelon varieties showed on **Table 7.** and the icebox type varieties showed on **Table 8.** are recommended for cultivation (marked with "x").

Table 7. Container sized watermelon combinations recommended for cultivation

SCION/ROOTSTOCK	*Titán*	*Carnivor*	*Nimbus*	*Argentario*	*Macis*	*Nun 3001*
Lonci		X	X	X	X	X
Sprinter				X	X	X
Early Beauty				X	X	X
Crimstar	X	X		X	X	
Crispeed		X	X	X		X

Table 8. Icebox type watermelon combinations recommended for cultivation

SCION/ROOTSTOCK	*Titán*	*Carnivor*	*Nimbus*	*Argentario*	*Macis*	*Nun 3001*
Susy	X		X	X	X	X
Boxi	X		X	X	X	X
ZKI 10-55						
WDL 9707				X		X
Tiger Baby	X	X	X	X	X	
Esmeralda	X		X	X		X

4. NEW SCIENTIFIC RESULTS AND RECOMMENDATIONS FOR PRACTICE

New scientific results of the watermelon and muskmelon field experiments and recommendations for the practice are the following:

4.1. New scientific results of the muskmelon field experiments

Results of the 2006-2011 muskmelon (*Cucumis melo* L.) grafting experiments are the following:

1. Recommendations have been made for scion-rootstock muskmelon combinations optimal for the production area of Hungary (Békés county), where the most intensive cultivation takes place.
2. By laboratory analysis (determination of refraction, dry matter content, acid and sugar content, antioxidant capacity and total polyphenol content), it has been proven that contrary to international data, grafting could improve fruit quality of muskmelons.
3. Results of the field experiments showed that grafted muskmelons have higher yields per plant than the non-grafted ones, which data have also been found in international literature.
4. It has been proven that the Brix˚ (water soluble dry matter content) and the sucrose content (responsible for the sweet taste) do not necessarily correlate, so it cannot be stated that a variety with high Brix˚ must also be sweet.
5. It can be said, that the total polyphenol content correlates with the ability of the plants to tolerate stresses.
6. Economic evaluation proved that using grafted muskmelon plants for growing has higher costs than that of using non-grafted seedlings. The results of the field experiments proved that safer cultivation and yields compensate for the higher costs.

4.2. Recommendations for muskmelon cultivation

Based on the results of the 2006-2011 muskmelon grafting experiments, the following recommendations are made:

1. The variety *Capri* included in the experiments for three years, is not recommended for open field cultivation, due to poor ability to tolerate extreme weather conditions, and has weak foliage and thin fruit skin. The *Galia* type variety *London* is recommended both grafted and non-grafted for open field cultivation.

2. The sugar content of *Donatello* was measured in two years. Grafting caused lower sucrose level in both years, thus in case of this variety, grafting is not recommended.
3. In case of antioxidant capacity and total polyphenol content, a clearly positive effect of grafting cannot be detected, since some combinations had higher, some had lower values. The ability to tolerate abiotic stresses of *Donatello* is worse, when it is grafted.

4.3. New scientific results of the watermelon field experiments

Results of the 2010-2011 watermelon (*Citrullus lanatus* [Thumb] Mansfeeld) grafting experiments are the following:

1. Recommendations have been made for scion-rootstock watermelon combinations (both container and icebox sized variety types) optimal for the production area of Hungary (Békés county), where the most intensive cultivation takes place.
2. The differences between the interspecific and *Lagenaria* type rootstocks have been confirmed. Recommendations were made, in which cases should they be used.
3. Sensory analysis proved that contrary to belief, the fruit taste of grafted plants it not always worse than that of the non-grafted ones. The factors that affect taste are: rootstock-scion combination, cultivation technology and fertilization.
4. Economic evaluation proved that using grafted watermelon plants for growing has higher costs than that of using non-grafted seedlings. The results of the field experiments proved that safer cultivation and yields compensate for the higher costs. In two of the three years (2010 and 2011), grafted plants produced more profit than the non-grafted ones.

4.4. Recommendations for watermelon cultivation

Based on the results of the 2010-2011 watermelon (*Citrullus lanatus* [Thumb] Mansfeeld) grafting experiments, the following recommendations are made:

1. Results proved that with the exception of the combination *Crispeed x Titán*, in each case the yield of grafted plants were higher. After the yield per plant value was conversed to yield per hectare, a correlation was detected between the two values in case of most varieties, which means grafting watermelons has a positive effect on the yield.
2. With a few exceptions, grafted plants had better vigor than the non-grafted ones. It is important that the interspecific *Nimbus* rootstock variety caused lower vigor in case of

Boxi in 2011 and *Susy* in 2010, than it was measured on the non-grafted plants. This could mainly be explained by the weather conditions.

3. In my opinion, *Sprinter* should only be grown grafted, since the non-grafted plants had a very low growth rate. In most cases, foliage of grafted plants had better regeneration than that of the non-grafted ones. In 2011, most varieties regenerated better when grafted on *Lagenaria* type rootstocks.
4. Results show that if container sized *Susy* is non-grafted, it produces larger fruits in some years, while grafted in every year. That is why it should be considered to put the variety *Susy* into the icebox size category.

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