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Cracking susceptibility of sour cherry (*Prunus cerasus* L.) in Hungary and relation to calcium application

Simon, G., Tóth, M. & Papp, J.

Horticultural Science Faculty, Department of Fruit Science, Corvinus University of Budapest, Villányi út. 29–43.

Summary: The rain induced fruit cracking is a big, serious problem especially for sour cherry growers but in some year sour cherry growers had also problem with fruit cracking caused by too much rainfall in the harvesting season. The cracked sour cherry fruits can be easily infected by different diseases like *Monillinia sp.* Cracked and infected fruits can not be transported for long distance and using for preservation because they lost their market value by the pour fruit quality. There are two possibilities to protect fruits against the rain induced fruit cracking. The most effective protection technique is the plastic rain cover over the tree rows. The installation of these equipments is too expensive for the growers. That is the reason why researchers tried to find other less expensive and sufficiently effective ways like sprayings different mineral salts, hormone and other type chemicals against the rain induced fruit cracking. Several calcium formulas calcium chloride ($CaCl_2$), calcium hydroxide ($Ca(OH)_2$) and calcium nitrate ($Ca(NO_3)_2$) can be sprayed in appropriate solution concentration.

The aim of our trial is to determinate the fruit cracking susceptibility of wide grown Hungarian sour cherry varieties and find the most effective calcium formula and its concentration for spraying in orchards to prevent the fruit cracking. In the first trial year (2006) cracking index of tested sour cherry varieties were determined under field and laboratory conditions. Under field conditions were not found differences between cracking tendency of tested cultivars. After results of immersing fruits in distillated water for 24 hours tested sour cherry varieties were divided to three groups by the susceptibility to rain induced fruit cracking: very susceptible ('Maliga emléke', 'Piramis', 'Érdi jubileum', 'Érdi nagygyümölcsü' and 'Meteor korai'); susceptible ('Érdi bőtermő', 'Pándy 279' and Cigány 59.; moderately susceptible/tolerant ("T" and "R" clones). In the second trial year (2007) calcium chloride ($CaCl_2$) and calcium nitrate ($Ca(NO_3)_2$) were sprayed in 0,35m/m%; 0,5m/m% and 1,0m/m% solution concentration. One more commercial product "Damisol-Kalcium" was also applied in the advised 1,0m/m% concentration. Like in the trial year before (2006) under field conditions we did not kept differences between the cracking susceptibility of varieties and calcium treatments. As the result of laboratory testing (immersing calcium treated fruits in distillated water) we kept that calcium chloride ($CaCl_2$) seems the most effective against the fruit cracking in 0,5m/m% solution concentration. The other calcium formulas also decreased the cracking ratio but in less scale.

Key words: sour cherry (tart cherry), fruit cracking, cracking index, calcium nitrate, calcium chloride, Damisol-Kalcium

Introduction

The rain induced fruit cracking is a big, serious problem especially for sour cherry growers but in some year sour cherry growers had also problem with fruit cracking caused by too much rainfall in the harvest season. A related problem is that fruit cracking facilitates decays of the fruit caused mainly by *Monilinia* spp. (*Holb*, 2003). The installation of these equipments is too expensive for the growers. That is the reason why researchers tried to find other less expensive and sufficiently effective ways like sprayings different mineral salts, hormone and other type chemicals against the rain induced fruit cracking (*Meli*, 1982; *Gillespie*, 1988; *Opperman*, 1988; *Pennel & Webster*, 1996; *Meland & Skjervheim*, 1998; *Børve & Meland*, 1998; *Balmer*, 1998). The installation of these equipments is too expensive for the growers. That is the reason why researchers tried to find other less expensive and sufficiently effective ways like sprayings different mineral salts, hormone and other type chemicals against the rain induced fruit cracking.

Spraying of cherry fruits with minerals or other chemicals:

There are many ports in the literature suggesting that sprays of mineral salts, fungicides and other chemicals reduce cherry cracking. Any compounds with positive effect in reducing fruit cherry fruit cracking maybe expected to have at least one of the following characteristics (*Christensen*, 1996):

- Cause o delay or reduces the amount of water uptake into the fruit;
- Increases transpiration of free water from the fruits surface;
- Improves the fruit skin (strength, plasticity or elasticity, cuticular properties).

Calcium sprayings reduce the cracking tendency of cracking:

Physiological background: Among the macro elements the calcium is taken up in the highest amount by fruit trees, but only at least amount of the up taken calcium is transported into the fruits. Calcium together with potassium plays very important physiological role in controlling of

plasma colloids and the strength of the cell walls (*Papp*, 1997). *Faust* (1989) noted tat the calcium is the most important element considering the fruit quality and storage life. The most of physiological disease and storage disorders of fruits are positive correlation wit calcium deficit.

Bangert (1968) observed 8 sweet cherry varieties and found positive correlation between the natural calcium content of cherry fruit and their cracking tendency. *Glenn & Poovaiah* (1989) showed that calcium treatments increase the strength and elasticity of cell walls of the fruit skin.

By opinion of *Sekse* et al. (2005) the most obvious effect of added calcium solution to the fruit surface is that it reduce the osmotic potential across the cuticle into the fruit. Consequently, this can reduce the osmotically driven transport of water trough the cuticle into the fruit, where the increasing sugar content of the ripening fruit create high osmotic pressure.

To take the positive physiological advantages of calcium shown above, recent times calcium treatment in sweet cherry orchards are suggested by the followings:

- calcium directly decreasing the amount of water taken up into the fruit through the skin and by this way cracking tendency is decreased;
- in a long-term effect calcium has positive effect on tissue structure, strength and elasticity of the fruit skin; and it has also positive effect on storage an shelf life too.

Many researchers had investigations to reduce the cherry fruit cracking by calcium sprayings (*Bullock*, (1952); *Ono* et. al. (1954); *Ackley*, (1956), *Bangerth*, (1968); *Christensen*, (1972, 1976); *Callan*, (1986); *Sekse*, (1987, 1995); *Meheriuk* et. al., (1991); *Cline*, (1995); *Grubich*, (1998); *Lang* et al. (1998); *Lang* and *Floree*, (1999), *Wermund* et al., (2005)).

The researchers who used the calcium sprayings in field trials to reduce the cherry fruit cracking noted the followings:

- Calcium chloride ($CaCl_2$) is showing good potential as a treatment for reducing rain cracking of cherries.
- Calcium chloride solution, when applied in response to rainfall, reduced the level of cracking on cherries.
- The effectiveness of the treatment varied between varieties, orchards and seasons. This variation is suggested to be partly due to different rainfall patterns between orchards and seasons. Some fine-tuning is required to match the environmental triggers to the application of $CaCl_2$ (i.e. to know in advance the level of rain required before the $CaCl_2$ is applied).
- The $CaCl_2$ treatment does not appear to affect maturity, fruit size or storage of cherries.
- In some orchards the major problem was deposits left on fruits by the quite concentrated sprays used.

Based on the results of trials with calcium chloride and applied growing technologies it seems 0,35–1,0% calcium chloride solution is effectiveness in cherry orchards to reduce the cracking tendency. It is possible to use traditional plant protection equipments for spaying with calcium solution before and during rain. There are some samples with fixed overhead sprinkling spraying with calcium solution during the rain.

Some other calcium salts can be used for spraying in appropriate concentration to reduce the fruit cracking such as calcium nitrate, calcium hydroxide.

There are some new results and opinion about the rain cover protection and calcium application. *Wermund* et al. (2005) published that in some cases and some sweet cherry varieties the calcium application reduced the fruit cracking much better than protection system did.

Materials and methods

In the first year of our trial the aim was to determine the susceptibility to rain induced fruit cracking of sour cherry market varieties grown Hungarian. 10 sour cherry cultivars were tested, 8 of them representing the Hungarian commercial variety sort ('Piramis', 'Meteor korai', 'Érdi nagygyümölcsű', 'Érdi jubileum', 'Érdi bőtermő', Maliga emléke', 'Cigány 59' and 'Pándy 279') and 2 new releases ('T' and 'R' clones).

Short introduction of the tested cultivars (Apostol, 2003):

'Piramis': It is ripening in the firs decade of June few days before cv. 'Meteor korai'. It has large to very large fruit size: the average diameter of fruits is 24–26 mm and the average fruit weight is 7–8 g. Its fruit quality similar to cv. 'Pándy'. The fruit skin and flesh is dark carmine red and moderately firm, the fruit juice is moderately stainy.

'Meteor korai': It is ripening in the first decade of June. The fruit size is medium: the average fruit diameter is 21–22 mm, the average fruit weight is 4,5–5,5 g. The fruit shape is fatted round. The fruit skin is dark carmine red and medium thin. The fruit juice is stainy. The taste is balanced, pleasantly sweet-acidic.

'Érdi nagygyümölcsű': It is ripening in the middle of June. The fruit is very large sized, the average fruit diameter is 23–25 mm, and the average fruit weight is around 6 g. The fruit skin is dark carmine red, full ripped is blackish red and medium thin. The fruit flesh is moderately firm and juicy. The taste is pleasantly sweet acidic.

'Érdi bőtermő': It ripens between 16th and 20th of June. The fruit is medium sized with 21–23 mm diameter and the average fruit weight is 5,6–6,0 g. The fruit shape is regularly rounded. The fruit flesh is moderately firm, dark red and the fruit juice is moderately stainy. The taste is pleasantly sweet acidic.

'Érdi jubileum': It has elongated ripening season from the beginning of June. It has regular rounded fruit shape. The fruit is medium sized with 21–23 mm diameter and the average fruit weight is 7,7–5,9 g. The colour of the fruit is depending on the maturity status carmine red to blackish red. The fruit flesh is very firm. The soluble solid content of fruits is high (at the beginning of the ripening the refraction is 12–13%, in full ripped status it can rich 22–23 ref.%.

'Maliga emléke:' Its ripening season starting around 20th of June. The fruit shape is fatted round. Fruits are very large sized, 23–25 mm diameter and fruit weight is 6,5–7,5. The fruit flesh is moderately firm, the fruit juice weak of colour. The taste is acidic sweet.

Cigánymeggy 59: Fruits are small sized with 18–20 diameters and 4g fruit weight. The fruit flesh is moderately firm and dark blackish purple coloured, and the fruit juice is stainy. The soluble solid and acid and sugar content are also high.

Pándy 279: This numbered clone has better fruit quality and grooving parameters than the basic cultivar. It is ripening in the end of June. The fruit size is middle large to large (diameter is 24–25 mm and fruit weight is 5–6 g) depending the crop load. The fruit flesh is dark red and moderately firm. The fruit juice is coloured slightly. Its taste is typical, acidic-sweet.

The tested two new releases by site selection from North-East part of Hungary:

„T"-clone: It was selected by Ferenc Szőke around Fényeslitke. It ripens in the beginning of June. In its appearance and fruit parameters is similar to the "Újfehértói fürtös". Fruits size is medium large (diameter is about 21,8mm and the average fruit weight is 5,3 g). The fruit flesh is firm and the fruit juice is moderately stainy. The sugar content is lower than the case of cv. 'Újfehértói fürtös'.

„R"-clone: It was selected by Ferenc Szőke around Lövőpetri. It is late ripening variety; the ripening season is in the beginning of July. The fruits are middle sized with 21,5 mm diameter and the average fruit weight is 5–5.5 g. Fruit skin is shiny red. The fruit flesh is firm with pleasure acidic-sweet taste. The fruit juice is moderately stainy.

'Újfehértói fürtös' variety was tested only in 2007 instead of "R" and "T" clones because they had serious spring frost damages in Újfehértó. It was selected from the same part of Hungary. Its fruit characteristics are similar to "R" and "T" clones.

The testing orchards were located in two different places in Hungary. One of them is the Research Station of Fruit and Ornamental Research Institute in Érd-Elvira, the second is Újfehértó Fruit Research Institute. The tested trees were standing on the same mahaleb rootstock and in the same spacing. 100 fruits were collected from each cultivar in ripening season twice (at the beginning of fruit colouring and about 85–90% ripening status of fruits) in the testing orchards. Harvesting times of tested cultivars are in *Table 1*. In the field trial it was counted the number cracked fruits the cracking ratio were calculated (%; number of cracked fruits per number of observed fruits* 100).

Table 1. The sampling times of the tested sour cherry varieties in 2006.

Cultivar / variety	Sampling time of fruits at the beginning of fruit colouring	Sampling time of fruits at 85–90% ripening status
Piramis	05.26.2006	06.02.2006
Meteor korai	05.26.2006	06.02.2006
Érdi nagygyümölcsű	05.31.2006	06.07.2006
Érdi jubileum	05.31.2006	06.07.2006
Érdi bőtermő	06.15.2006	06.22.2006
Maliga emléke	06.15.2006	06.22.2006
Cigány 59	06.15.2006	06.27.2006
Pándy 279	06.22.2006	06.29.2006
„T"-klón	–	06.03.2006
„R"-klón	–	06.03.2006

In the same sampling times 100 fruits were collected from each variety for testing under laboratory conditions. First the total weight of 100 fruits was measured and the average fruit weight was calculated. To measure firmness and skin strength a "QB-129" -type fruit examinator was used on 10 fruits repeated 3 times (data of firmness are in Kp/cm^2). The refr.% on 10 fruits repeated 3 times with a "ATAGO PAL-1" type digital refractometer (refr.% is in Brix%). It was measured the weight of 100 fruits and the same 100 fruits were immersed in distillated water. After 2, 4, 6, 8, 10, 12, 18, 24 hours the cracked fruits were counted and the cracking ratio were calculated and the total weight of 100 fruits was also measured in the same times.

By the results of the first year the tested varieties were divided three groups by susceptibility to rain induced fruit cracking: very susceptible; susceptible; moderately susceptible (tolerant). In the second year of the trials each treatment were applied on two varieties from the three groups. The tested varieties in this year were the followings: Two calcium formulas (calcium chloride and calcium nitrate) in three concentrations of solutions (0,35 m/m%; 0,5 m/m% and 1,0 m/m%) were applied on the tested varieties. A commercial product ("DAMISOL –Kalcium") containing calcium (calcium oxide and calcium nitrate in solution) was also applied in the same time in the offered 1,0 m/m%. Untreated fruits were collected as the control. Treatments were applied twice in each variety. The first application (spraying with different concentration calcium formulas) was about 2 week before. The time of calcium treatments and the harvesting time (sampling time) are shown in *Table 2*. For the field sprayings "SOLO 425" manual spraying machine was used.

Table 2. Applying times of different calcium formulas and the harvesting time in the year 2007.

Cultivar	Time of the first treatment	Time of the second treatment	Harvesting time
'Meteor korai'	18th of May 2007.	28th of May 2007.	10th of June 2007.
'Érdi jubileum'	18th of May 2007.	28th of May 2007.	10th of June 2007.
'Maliga emléke'	24th of May 2007.	04th of June 2007.	18th of June 2007.
'Érdi bőtermő'	24th of May 2007	04th of June 2007.	12th of June 2007.
'Pándy 279'	12th of June 2007.	18th of June 2007.	25th of June 2007.
'Újfehértói fürtös'	12th of June 2007.	18th of June 2007.	27th of June 2007.

In the field and in laboratory the same observations were done on the 7 treatments and the control as the year before.

Results and discussion

Results in the first trial year in 2006.

The average fruit weight: The average fruit weight: In four cases of tested sour cherry cultivars ('Érdi nagygyümölcsű', 'Érdi bőtermő', 'Érdi jubileum' és 'Cigány 59' – cells signed

with gray background in *Table 3*) the average fruit weight was lower than fruit weight mentioned in the literature (*Apostol*, 2003). The reason could be that we sampling the fruits in 85–90% ripening status when in the orchards the harvesting is usually beginning not in full ripped status. In the case of the other six varieties are in agreement with the literature (*Apostol*, 2003) and four of them ('Maliga emléke', 'Pándy 279', „R"-clone, „T"-clone) had higher average fruit weight than was mentioned in the literature (*Apostol*, 2003.; *Table 3; and Figure 1*).

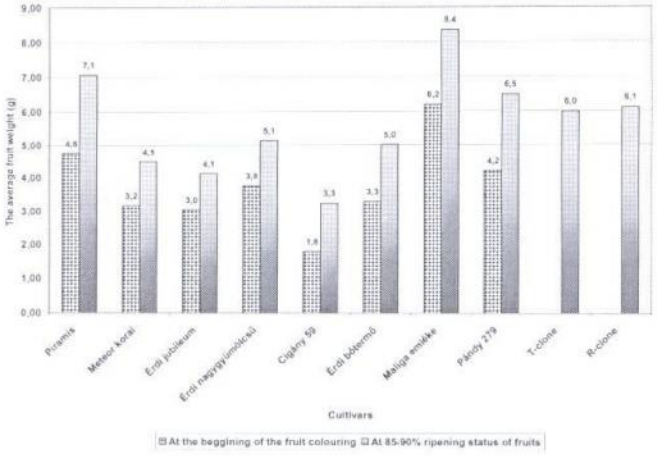

Figure 1. the average fruit weight according to the sampling time* (at the beginning of fruit colouring and at 805–90% maturity status; Érd–Elvira, Újfehértó, 2006.)
Note: * the exact sampling times are shown *in Table 1.*

Table 3: The average fruit weights of the tested sour cherry cultivars related data in the literature (Érd–Elvira, Újfehértó, 2006).

Cultivar	The average fruit weight in the test orchards (g)	The average fruit weight in the literature* (g)
'Maliga emléke'	8.4	6.5–7.5
'Piramis'	7.1	7.0–8.0
'Pándy 279'	6.5	5.0–6.0
„R"-clone	6.1	5–5.5
„T"-clone	6.0	5.3
'Érdi nagygyümölcsű'	5.1	6.0
'Érdi bőtermő'	5.0	5.6–6.0
'Meteor korai'	4.5	4.5–5.5
'Érdi jubileum'	4.1	4.7–5.9
'Cigány 59'	3.3	4.0

* (*Apostol*, 2003)

Cracking test under field conditions: Under field conditions were not found valuable – significant differences in the fruit cracking susceptibility of tested sour cherry cultivars. In the case of the most sour cherry variety we did not found any cracked fruits – except in the case of 'Piramis'. Fruit cracking data of the tested sour cherry varieties under field conditions are shown in *Table 4.*

The water induced fruit cracking susceptibility of sour cherry cultivars under laboratory conditions (fruits were immersed in distillated water):

By the literature (*Christensen*, 1996) the fruits are more susceptible to fruit cracking when they are closer the full

Table 4. The cracking ratio (% of the cracked fruits) in the field trial according to the sampling time (Érd–Elvira, Újfehértó, 2006)

Cultivar	At the beginning of fruit colouring	At 85–90% maturity status
'Piramis'	8.3%	11.9%
'Meteor korai'	0%	0%
'Érdi nagygyümölcsű'	0%	0%
'Érdi jubileum'	0%	0%
'Érdi bőtermő'	0%	0%
'Maliga emléke'	0%	1.6%
'Cigány 59'	0%	0%
'Pándy 27'9	0%	0%
„T"-clone	0%	0%
„R"-clone	0%	0%

maturity status. That was the reason why fruits were sampling in two difference fruit maturity status, at the beginning of fruit colouring and at 85–90% maturity status. The beginning colouring of is about 7–10 days before harvest and in the most commercial orchard growers are starting the picking about 85–90% maturity status.

At the beginning of fruit colouring the immersed fruits in distillated water cracked in different scale. Also significant differences were found in fruit cracking dynamics of tested varieties.

At the beginning of fruit colouring (7–10 days before starting harvest) 'Maliga emléke' was the most susceptible to rain induced fruit cracking, the ratio of cracked fruits was 25% after 2 hours immersing in distillated water and immersed for longer time it had also high cracking susceptibility. Cracking susceptibility data of tested sour cherry varieties are shown in *Table 5*, but the cracking tendency by the time and varieties are seen more clearly in *Figure 2*. By the cracking susceptibility of tested varieties at the beginning of fruit colouring immersed in distillated water for 12 and 24 hours were ranking, data shown in *Table 6*.

In the case of fruits in 85–90% maturity status there were found differences in the cracking ratio and the cracking dynamics of the tested varieties when they were immersed in distillated water for 24 hours (data are shown in *Table* 7 and Figure 3).

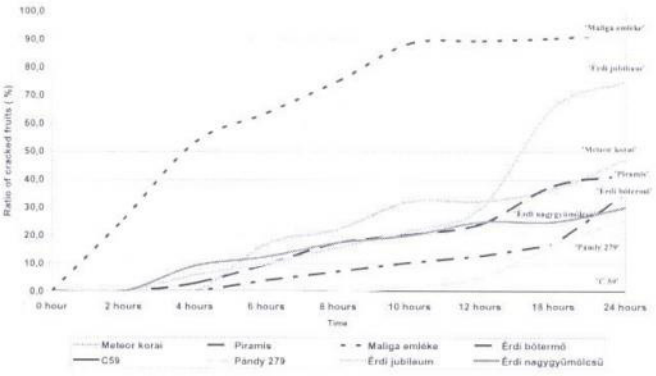

Figure 2 Cracking susceptibility (cracking ratio in%) of the tested sour cherry cultivars at the beginning of the fruit colouring according to immersing time in distillated water (2006).

Table 5. Cracking susceptibility (cracking ratio in%) of the tested sour cherry cultivars at the beginning of the fruit colouring according to immersing time in distillated water (2006).

	Meteor korai	Piramis	Maliga emléke	Érdi bőtermő	Cigány 59	Pándy 279	Érdi jubileum	Érdi nagygyümölcsű
0 hours	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 hours	0.0	0.0	25.7	0.0	0.0	0.0	0.0	0.0
4 hours	0.0	2.9	53.3	0.0	0.0	0.0	5.8	9.2
6 hours	17.0	9.7	63.8	4.0	0.0	0.0	10.0	12.5
8 hours	22.3	17.5	75.2	7.2	0.0	0.0	15.8	17.5
10 hours	32.1	20.4	88.6	10.4	0.0	1.7	21.7	20.0
12 hours	32.1	24.3	89.5	12.8	0.0	5.0	30.0	25.0
18 hours	36.6	37.9	90.5	16.8	0.0	16.7	65.8	25.0
24 hours	47.3	41.7	92.4	35.2	0.0	25.8	75.0	30.0

Table 6 Order of rank by cracking susceptibility (cracking ratio in%) of the tested sour cherry cultivars at the beginning of the fruit colouring according to immersing time in distillated water (2006).

time	Rank of order							
	8.	7.	6.	5.	4.	3.	2.	1.
12 hours	Cigány 59	Pándy 279	Érdi bőtermő	Piramis	Érdi nagygyümölcsű	Érdi jubileum	Meteor korai	Maliga emléke
24 hours	Cigány 59	Pándy 279	Érdi nagygyümölcsű	Érdi bőtermő	Piramis	Meteor korai	Érdi jubileum	Maliga emléke

*Note: 1- the most susceptible; 8 – the least susceptible

Table 7. Cracking susceptibility (cracking ratio in%) of the tested sour cherry cultivars in 85–90% maturity status according to immersing time in distillated water (2006).

	Meteor korai	Piramis	Maliga emléke	Érdi bőtermő	Cigány 59	Pándy 279	Érdi jubileum	Érdi nagygyümölcsű	T-clone	R-clone
0 hour	0	0	0	0	0	0	0	0	0	0
2 hours	1.7	24.6	7.5	0.0	0.0	0.0	0.0	10.0	0.0	0.0
4 hours	5.1	37.3	19.2	0.0	0.8	0.0	6.7	20.0	0.8	0.0
6 hours	10.2	54.2	55.0	3.3	3.3	0.0	16.7	34.2	0.8	0.0
8 hours	20.3	62.7	71.7	4.2	4.2	0.0	34.2	50.0	0.8	0.0
10 hours	33.1	72.0	76.7	11.7	5.8	6.7	40.0	54.2	0.8	0.0
12 hours	47.5	83.9	82.5	23.3	12.5	15.8	49.2	59.2	0.8	0.8
18 hours	75.4	89.8	91.7	44.2	33.3	34.2	84.2	79.2	2.5	1.7
24 hours	82.2	96.6	96.7	66.7	45.0	55.0	91.7	87.5	3.3	1.7

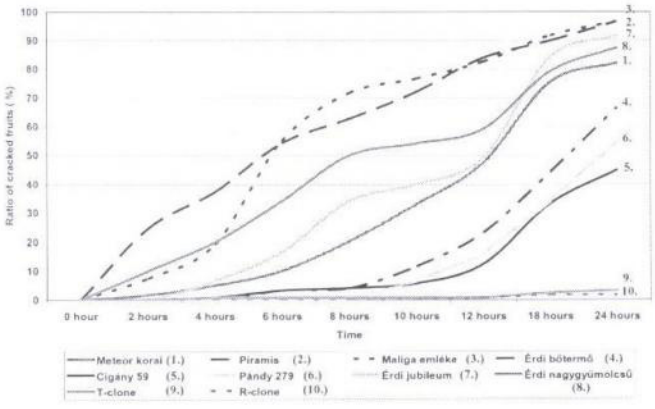

Figure 3 Cracking susceptibility (cracking ratio in%) of the tested sour cherry cultivars in 85–90% maturity status according to immersing time in distillated water (2006).

By the cracking susceptibility of tested varieties in 85–90% maturity status immersed in distillated water for 12 and 24 hours were ranking, data shown in *Table 8.*

By these results after the first trial year the followings conclusions done:

- It was found that sour cherry fruits were more susceptible to rain induced fruit cracking in 85–90% maturity status than at the beginning of fruit colouring. When fruits were closer to the full ripped status they were more sensible to fruit cracking for shorter time water immersing, and also the scale of the fruit cracking was more serious than earlier in the ripening season. Our results are in agreement with *Christensen*'s (1996) opinion that cherry fruits are more susceptible to fruit cracking in their ripening process.
- We could not find close relationship between the scale of water absorption and the rise of the fruit volume. There

Table 8. Order of rank by cracking susceptibility (cracking ratio in%) of the tested sour cherry cultivars in 85-90% maturity status according to immersing time in distillated water (2006).

time	Rank of order									
	10.	9.	8.	7.	6.	5.	4.	3.	2.	1.
12 hours	R-clone	T-clone	Cigány 59	Pándy 279	Érdi bőtermő	Meteor korai	Érdi jubileum	Érdi nagy-gyü mölcsü	Maliga emléke	Piramis
24 hours	R-clone	T-clone	Cigány 59	Pándy 279	Érdi bőtermő	Meteor korai	Érdi nagy-gyümölcsü	Érdi jubileum	Piramis	Maliga emléke

*Note: 1- the most susceptible; 8 – the least susceptible

was no correlation the quantity of absorbed water with the fruit cracking in both observed fruit maturity status. It was concluded by one year data more detailed studies on these data should be carried out in the future.

- The sugar content of the fruits did not have effect on the cracking tendency of the fruits. Earliar *Verner & Blodget* (1931) had that conclusion that fruit cracking was directly affected by the osmotic concentration of the fruit juice. In contrast this our results confirm Tucker's opinion that the sugar content is not correlation with the cracking tendency of cherry fruits (*Tucker*, 1934).
- We did not found close relationship between the fruit firmness and the cracking tendency of sour cherry fruits. It was based on one year results, further more trials are needed because this result is in contrast with Christensen's opinion that cherry cultivars with firmer fruits are more prone to fruit cracking than softer ones (*Christensen*, 1996).
- By fruit cracking trials done parallel in the same orchard with three hard fleshed sweet cherry cultivars ('Germersdorfi óriaás', 'Katalin' and 'Kavics') that generally opinion can be modified that sour cherry cultivars are less prone to rain induced fruit cracking than sweet cherries (*Christensen*, 1996). It was found that the cracking ratio of very cracking susceptible sour cherry varieties had same or higher cracking index than observed sweet cherries. Data are shown in *Table 9*.
- The final conclusion of the first trial year was grouping of tested sour cherry varieties by fruit cracking tendency under laboratory condition (immersing in distillated water). Tested cultivars were divided three groups: very susceptible; susceptible; moderately susceptible (tolerant). Groups with varieties are shown in *Table 10*.

Table 9 Cracking tendency (cracking ratio in%) of harvest ripped hard fleshed sweet cherry varieties according to immersing time in distillated water. (2006)

immersing time	Sweet cherry cultivars		
	Germersdorfi 3.	Katalin	Kavics
0 hour	0.0	0.0	0.0
2 hours	0.0	0.0	0.0
4 hours	13.3	0.0	10.0
6 hours	29.2	5.0	12.0
8 hours	44.2	10.0	16.0
10 hours	49.2	26.0	20.0
12 hours	54.2	39.0	51.0
18 hours	85.0	70.0	83.0
24 hours	85.0	77.0	93.0

Table 10 Grouping of tested sour cherry varieties by fruit cracking tendency under laboratory condition (immersing in distillated water) (2006).

Very susceptible:	Susceptible (Seensitive):	Moderately susceptible (tolerant)
'Maliga emléke', 'Piramis', 'Érdi jubileum', 'Érdi nagygyümölcsü' and 'Meteor korai'	'Érdi bőtermő', 'Pándy' and Cigány 59.	„T" and „R" clones as new releseases

Results in the second trial year in 2007.

The aim of the second trial year was to find the most effective calcium formula and its concentration for spraying in orchards to prevent the fruit cracking. In the second trial year we observed 6 sour cherry cultivars('Maliga emléke', 'Érdi jubileum', 'Meteor korai', 'Érdi bőtermő', 'Pándy 279' and 'Újfehértói fürtös'). calcium chloride ($CaCl_2$) and calcium nitrate ($Ca(NO_3)_2$) were sprayed in 0,35m/m%; 0,5 m/m% and 1,0 m/m% solution concentration. One more commercial product "Damisol-Kalcium" was also applied in the advised 1,0 m/m% concentration. Like in the trial year before (2006) under field conditions we did not kept differences between the cracking susceptibility of varieties and calcium treatments.

The average fruit weight: The average fruit weights were measured by cultivars and treatments too. In the literature the average fruit weights are the followings: 'Meteor korai': 4.5–5.5g; 'Érdi jubileum': 4.7–5.9g ; 'Maliga emléke': 6.5–7.5g; 'Érdi bőtermő': 5.6–6.0g; 'Pándy 279: 5.0–6.0g'; 'Újfehértói fürtös':5.0–5.5g. Cells with gray background containing less fruit weight data than in the literature in *Table 11*. It is interesting that 'Meteor korai' last yeas was near to the lover limit; 'Érdi jubileum'fruits were more less related the average size than this year. Differences in average fruit weight between the two trial years can be caused by latent deficit of nutrients or over cropping. Probably the second cause is closer to the truth because in both years there were optimal weather conditions for the fruit set. In 2007 Érd-Elvira was free from spring frost damages and therefore good yield was harvested.

The fruit firmness: The fruit firmness and skin strength of tested varieties was measured by "QB-129" type fruit examinator. Fruits firmness (elasticity) was measured by destructive method when juice was coming out from fruits. The measured fruit firmness data by the sprayed calcium formulas in the average of the applied concentrations and the

Table 11. The average fruit weight by treatments in 2007 compared to data in 2006 (Érd-Elvira Major).

Cultivars	2006	Controll	$CaCl_2$ 0,35%	$CaCl_2$ 0,5%	$CaCl_2$ 1,0%	$Ca(NO_3)_2$ 0,35%	$Ca(NO3)_2$ 0,5%	$Ca(NO_3)_2$ 1,0%	Damisol-Kalcium
'Meteor korai'	4.5	4.25	4.25	4.27	4.53	4.50	4.53	4.50	4.03
'Érdi jubileum'	4.1	5.10	4.23	4.40	4.92	4.30	4.78	5.57	4.70
'Maliga emléke'	8.4	7.30	7.35	7.55	7.72	7.67	7.43	7.00	7.85
'Érdi bőtermő'	5.0	6.68	6.45	5.90	6.42	5.73	5.72	5.22	6.40
'Pándy 279'	6.5	6.65	6.27	6.40	6.08	6.40	6.20	6.53	6.33
'Újfehértói fürtös'	–	5.50	5.67	6.08	5.73	5.68	6.22	6.17	5.88

Table 12. The fruit firmness (Kp/cm^2) by the sprayed calcium formulas in the average of the applied concentrations and the used varieties. (Érd-Elvira Major, 2007.)

Used calcium formulas	Fruit firmness (Kp/cm^2)	Homogene groups	Difference related to the control (%)
Control	0.971	a	100.0
Calcium chloride	1.052	ab	108.3
Calcium nitrate	1.060	ab	109.1
Damisol-Kalcium	1.132	b	116.6

* Note: SzD5%=0,113

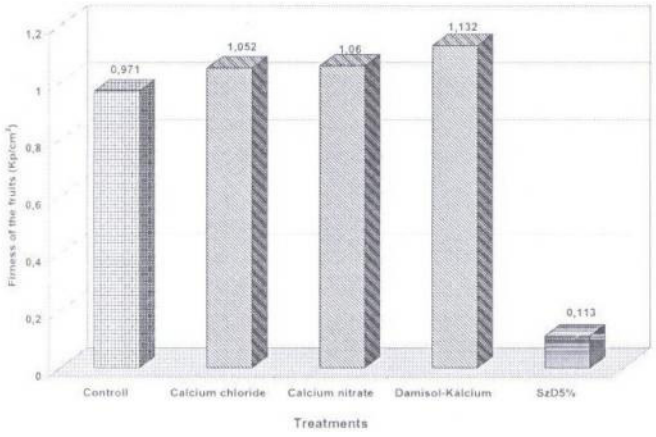

Figure 4 Changing of the fruit firmness in the case of $CaCl_2$ and $Ca(NO_3)_2$ treatments by the concentrations in the average of the used varieties. (Érd-Elvira Major, 2007.)

Table 13 Changing of the fruit firmness in the case of $CaCl_2$ and $Ca(NO_3)_2$ treatments by the concentrations in the average of the used varieties. (Érd-Elvira Major, 2007.)

Treatments	Fruit firmness (Kp/cm^2)	Homogene groups	Difference related to the control (%)
Control	0.971	a	100.0
Calcium chloride 0,35%	1.015	ab	104.5
Calcium chloride 0,5%	1.077	ab	110.9
Calcium chloride 1,0%	1.065	ab	109.7
Calcium nitrate 0,35%	1.037	ab	106.8
Calcium nitrate 0,5%	1.083	ab	111.5
Calcium nitrate 1,0%	1.060	ab	109.1

* Note: SzD5%=0,148

used varieties are in *Table 12*. Fruits sprayed with 1m/m% "DAMISOL-Kalcium" were significantly firmer by 16% than untreated fruits. Sprayed calcium nitrate and chloride give higher fruit firmness by 8–9% but these differences were not significant (*Table 12* and *Figure 4*).

In the average of tested varieties all the sprayed concentrations of calcium chloride and calcium nitrate gave firmer fruits than the control, but differences related the control were no significant (*Table 13*). By the data of Table 13 it is seen that 0,5 m/m% concentration of calcium chloride and nitrate gave the hardest fruits from treated fruits with different concentration.

Total sugar content of fruits: The total sugar content was measured by "ATAGO PAL-1" digital refractometer in Brix%. All the sprayed calcium formulas gave fruits with lower total sugar content than the untreated control. In the case of calcium chloride and nitrate differences related to the

Table 14 The total sugar content by the used calcium formulas in the average of the applied concentrations and the used varieties. (Érd-Elvira Major, 2007.)

Used calcium formulas	Total sugar content (Brix%)	Homogene groups	Difference related to the control (%)
Control	15.420	c	100.0
Caclium chloride	14.334	a	92.9
Calcium nitrate	14.164	a	91.8
Damisol-Kalcium	14.858	b	96.4

*Note: $SzD_{5\%}$=0.348

Table 15 Changing of the total sugar content in the case of $CaCl_2$ and $Ca(NO_3)_2$ treatments by the concentrations in the average of the used varieties. (Érd-Elvira Major, 2007.)

Treatment	Total sugar content (Brix%)	Homogene groups	Difference related to the controll%
Control	15,420	d	100,0
Calcium chloride 0,35%	14,330	abc	92,9
Calcium chloride 0,5%	14,058	ab	91,2
Calcium chloride 1,0%	14,620	bc	94,8
Calcium nitrate 0,35%	14,060	ab	91,2
Calcium nitrate 0,5%	13,978	a	90,6
Calcium nitrate 1,0%	14,455	abc	93,7

*Note: $SzD_{5\%}$=0.579

Table 16. The effect of the used calcium treatments on the rain induced fruit cracking in the average of very susceptible cultivars ('Meteor korai', 'Maliga emléke' and 'Érdi jubileum') – the cracking index (ratio of the cracked fruits in%) under laboratory conditions (fruits immersed in distillated water).

Hours	Controll	$CaCl_2$ 0,35%	$CaCl_2$ 0,5%	$CaCl_2$ 1,0%	$Ca(NO_3)_2$ 0,35%	$Ca(NO_3)_2$ 0,5%	$Ca(NO_3)_2$ 1,0%	Damisol-Kalcium
0 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 hours	7.22	1.67	2.78	0.00	1.11	3.33	1.67	3.89
8 hours	16.11	10.56	11.83	15.00	16.67	18.33	12.78	13.89
12 hours	26.67	16.11	19.51	27.22	23.33	26.67	30.67	29.44
16 hours	40.56	26.67	31.42	40.00	32.78	37.22	48.33	50.56
20 hours	48.33	30.00	37.42	50.00	36.11	48.89	62.78	58.89
24 hours	57.22	37.22	42.32	57.78	42.78	56.11	71.11	66.67

Table 17. The effect of the used calcium treatments on the rain induced fruit cracking in the average of susceptible cultivars ('Érdi bőtermő' and 'Pándy 279') – the cracking index (ratio of the cracked fruits in%) under laboratory conditions (fruits immersed in distillated water).

Hours	Controll	$CaCl_2$ 0,35%	$CaCl_2$ 0,5%	$CaCl_2$ 1,0%	$Ca(NO_3)_2$ 0,35%	$Ca(NO_3)_2$ 0,5%	$Ca(NO_3)_2$ 1,0%	Damisol-Kalcium
0 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 hours	5.83	1.67	0.00	0.0	3.33	0.83	0.00	0.83
8 hours	12.50	8.33	0.83	0.83	7.50	2.50	2.50	2.50
12 hours	20.00	12.50	1.67	2.50	9.11	5.83	3.33	6.67
16 hours	34.17	25.83	6.67	8.33	25.00	13.33	8.33	21.67
20 hours	40.83	32.5	14.17	15.83	31.67	25.83	15.83	34.17
24 hours	48.33	46.67	27.50	27.60	44.17	38.33	27.50	50.83

Table 18. The effect of the used calcium treatments on the rain induced fruit cracking in the average of moderately susceptible(tolerant) cultivar ('Újfehértói fürtös') – the cracking index (ratio of the cracked fruits in%) under laboratory conditions (fruits immersed in distillated water).

Hours	Controll	$CaCl_2$ 0,35%	$CaCl_2$ 0,5%	$CaCl_2$ 1,0%	$Ca(NO_3)_2$ 0,35%	$Ca(NO_3)_2$ 0,5%	$Ca(NO_3)_2$ 1,0%	Damisol-Kalcium
0 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20 hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24 hours	3.33	0.00	0.00	0.00	0.00	3.33	0.00	0.00

control were 7–8% and only 3,5% in the case of "DAMISOL-Kalcium" but these differences were significant (*Table 14*). It is in agreement with that general opinion that calcium treatment is delaying the ripening process and fruits are full ripped later (*Faust & Shear*, 1972; *Papp*, 2003). In our trial calcium treated and untreated fruits were sampled in the same time and that caused the lower total sugar content of calcium treated fruits because calcium treated fruits were delayed about 3–5 days in the ripening process.

All the calcium chloride and nitrate applications gave fruits with lower total sugar content than the control. The scales of differences related to the control were varied by the sprayed calcium formulas and concentrations (*Table 15*).

The fruit cracking index: Immersing fruits in distillated water under laboratory conditions the number of cracked fruits was counted and cracking indexes were calculated. The effect of different calcium formulas and concentrations on the fruit cracking by the immersing time and cracking susceptibility groups are presented in *Table 16*, *Table 17* and *Table 18*. The three most effective combinations of calcium formulas and concentrations are signed with gray background.

In the case of the very susceptible group of tested cultivars $CaCl_2$ 0,35 m/m%, $CaCl_2$ 0,5 m/m% and $Ca(NO_3)_2$ 0,35 m/m% treatments reduced similarly the highest scale the fruit cracking (*Table 16*).

The following treatments gave the highest fruit cracking reduction effects on the sour cherry cultivars depending to susceptible (sensitive) group: $CaCl_2$ 0,5m/m%, $CaCl_2$ 1,0m/m% and $Ca(NO_3)_2$ 1,0m/m% (*Table 17*).

By data of *Table 18* it is seen that in the case of moderate susceptible (tolerant) cultivar there were no effect of any calcium formulas or concentrations. These cultivars are not prone to rain induced fruit cracking, without any calcium spraying. The reason why these varieties can be sprayed with different calcium formulas is to increase the fruit firmness.

Summary conclusions related the applied calcium formulas and concentrations

Calcium chloride 0.35 m/m%:

By two applications in ripening season we could achieve only slight fruit firmness increasing (4–5%) in the average of the tested sour cherry varieties. It is suggested to use in the case of varieties which are very susceptible to rain induced fruit cracking and it reduced the ratio of cracked fruits by 20%. In the case sensitive group of sour cherry varieties it reduced the fruit cracking slightly by 1–2% related to the control.

Calcium chloride 0.50 m/m%:

By two applications in ripening season it increased the fruit firmness increasing by about 10%. It is suggested to use in the case of varieties which are very susceptible to rain induced fruit cracking and it reduced the ratio of cracked fruits by 20%. It reduced the highest scale the ratio of cracked fruits, in the case very susceptible group it reduced the fruit cracking by15% related to the control, in the case of sensitive group by 20%.

This calcium formula and concentration is generally suggested for increasing the fruit firmness (for mechanical harvesting, for long distance transporting) and in rainy harvest season to reduce the cracking tendency of sour cherry varieties.

Calcium chloride 1.0 m/m%:

By two applications in ripening season it increased the fruit firmness increasing by about 10%. In the case of very susceptible group it did not reduced the ratio of cracked fruits but applied on sensitive group it reduced the fruit cracking tendency in the same scale (by 20%) as 0.5% concentration.

It is suggested to use for increasing the fruit firmness for mechanical harvest or long distance transportation. It is suggested too to use for fruit cracking reduction of the sensitive group of sour cherries.

Calcium nitrate 0.35 m/m%:

By two applications in ripening season it increased the fruit firmness by 6–7% in the average of the tested sour cherry varieties. Its fruit cracking reduction effect is about 15% in the case of very susceptible cultivar group but on sensitive group it was only 4–5%.

It is suggested to use for fruit cracking reduction only in the case of sensitive sour cherry cultivars to fruit cracking.

Calcium nitrate 0.5 m/m%:

In the average of the tested six sour cherry cultivars it increased the fruit firmness and skin strength by 11.5%. In the case of very susceptible group it did not reduced the ratio of cracked fruits but applied on sensitive group it reduced the fruit cracking tendency in the same scale (by 20%) as 0.5% concentration.

It is suggested to use for increasing the fruit firmness for mechanical harvest or long distance transportation. It is suggested too to use for fruit cracking reduction of the sensitive group of sour cherries.

Calcium nitrate 1.0 m/m%:

In the average of the tested sour cherry varieties it increased the fruit firmness by 9% related to the control. In the case of very susceptible group the treated fruits cracked in higher ratio (by 15%) than untreated fruits that means it can not be used for this cracking susceptibility group. In contrast in the case of sensitive group it gave similar cracking reduction effect to the most effective 0,5m/m% calcium chloride treatment. By the experienced differences between the two cracking susceptibility groups it is necessary to make control test in the future to see clearly its effect on the fruit cracking, so now its usage is not preferred.

"Damisol-Kalcium" 1.0 m/m%:

It was found that Damisol –Kalcium treatment gave significantly higher fruit firmness (firmer by 16,6%) in the average of tested varieties. As the results of laboratory testing (dipping in distillated water as modeling the raindrop cover) "Damisol-Kalcium" treatments on very susceptible and susceptible sour cherry cultivars caused slightly higher (2–9%) fruit cracking.

This market product can be suggested to use only those sites of Hungary where the risk of heavy rains in the ripening season is low or in the case of varieties with low susceptibility to fruit cracking (cultivars selected from North-East part of Hungary).In these cases it has low risk to increase the fruit cracking besides making fruits firmer.

Conclusions after the second trial year

- By the application of different calcium formulas the firmness and skin strength of sour cherry fruits can be increased. The scale of fruit firmness increasing depends on the applied calcium formulas and the concentrations.
- Our experiences harmonize with those opinions that application of calcium in ripening season has delaying effect on the ripening process (*Faust & Shear*, 1972; *Papp*, 2003).
- The applied calcium formulas are effecting to reduce the rain induced fruit cracking of sour cherries. The scale of fruit cracking reducing effect depends on the applied calcium formulas and the concentrations
- Similarly the trial year before in 2007 we did not found close relationship between the fruit firmness and the cracking tendency of sour cherry fruits like *Christensen* (1996) thought earlier. It seems that in the background other varietal characters and physiological conditions are playing more important role in the fruit cracking.

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