# ASSESSMENT OF SOME MATURITY INDICATORS AND FRUIT GROWTH IN THREE APPLE CULTIVARS

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## Abstract

The continual increase of local apple production urges the optimization of all factors that impact fruit quality and quantity, in particular to those destined for long-term cold storage. Among them, the harvest dates of each apple cultivar intended for long-term storage are of great importance to the final freshness and quality of the fruits. In developed countries, those dates are being determined through the frequent assessment of some fruit maturity indicators, of which the most popular include: fruit firmness, total soluble solids and starch conversion. On the other hand, picking up apples when they have reached their maximum fruit weight increases the growers' income. It has been shown that such issues are not sufficiently known by the respective stakeholders in our country. This study was focused on assessing the progress of the abovementioned maturity indicators and fruit weight in 2012 of three main Korça region apple cultivars, Golden Delicious, Red Chief and Granny Smith. The measurements were made in five day intervals, five times for the first two cultivars and six times for Granny Smith. There was not found any significant difference between the optimal harvest dates for long-term storage of respective cultivars, despite from their location. Fruit growth continued very slightly after those days, to reach their maximum weight. The results were similar to the outcomes of same studies made in other countries. It has been argued the importance of appropriate harvest scheduling for each apple cultivar, based on fruit destination, as another way to increase the efficiency and incomes.

*Keywords:* apple, maturity, long-term storage, weight.

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## Introduction

The apple fruit production is increasing rapidly in Albania, particularly those 5- 6 recent years. That's due to growing demand for fresh fruit and vegetables of local consumers, as well as the farmers' interest to expand their cultivated areas with apple trees, as such a fruit has generated higher revenues than other crops, especially cereals. On the other hand, the support of Albanian government with grants for new apple orchards and cold storages for them has positively impacted the sector. In the past twenty years, Albania has imported huge amounts of apples, while nowadays the internal market demand is meet, and modest quantities are being exported. In the mid - long term, enter in mass production of the new intensive apple orchards will further increase the apple amounts. Under such circumstances, to keep the sector profitable, a round year apple availability would be required, which consequently requires their long term cold storage.

Several authorsin their works have found that in addition to ensuring the right cold storage parameters (temperature, relative humidity, air elements ratio, etc.), an important role in apple quality after refrigeration plays the harvest date of each cultivar. That is related to fruit maturity stage in the moment they are put in cold storage(Vielma et al., 2008; Kvikliene, 2001; Franelli, Casera, 1996; Streif, 1996). To get the best quality, each apple cultivar should be harvested just before entering the climacteric period, which means a bit before starting the massive production of ethylene and respiration activity (Little & Holmes 2000) and the harvest to be completed shortly, within several days (Blanpied&Silsby 1992). That's the best time for refrigeration. According to the literature, each apple cultivar has its own optimal harvest time, which may change from year to year. If fruits are harvest much in advance related to that optimal time, their growth is not completed, thus they are of a smaller weight, have less flavor and untypical cultivar color. In addition, during refrigeration such fruits are more susceptible to superficial scald, bitter pit, internal disorders, etc. (Blanpied&Silsby 1992) and lose more weight, as their cuticle is not fully formed. On the other hand, if such an optimal harvest time is exceeded, apple fruits cannot stand longer in refrigeration, as they are quickly soften, produce non-characteristic aromas and are more prone to diseases and rotting. Apple cultivars have a great variability between each other regarding their maturity time. Even more, the maturity date of same cultivar may change each year, sometimes more than 2-3 weeks (Beaudry, 2012). That's depended on the bloom dates and temperatures, especially in the first phase of fruit growth. On the other hand, the fruit growth follows aexponential-linear model (Goudriaan&Monteith 1990). According to that model, apple fruits increase initially their volume and weight exponentially due to continues cell division, while later on until harvest the growth is linear based on increase of existing cell size only. During the fruit maturation time, the growth rate decreases and it stops when fruitsare totally mature (Beaudry et al. 1993).

In the developed countries, determination of apple maturity destined for cold storage is an annual process based on maturity indices. In many EU countries, the Streif Index widely is used for that purpose, which comes as a ratio of fruit firmness with production of total soluble solids and starch index (Streif, 1983, 1996).

In our country there have not been such applicative studies regarding physiological processes of pre and post-harvest of apples and interaction of agro-technical and environmental factors on apple quality, shelf-life and weight. The harvest period has been mainly based on empiric methods and organoleptic estimation of apple fruits by producers and cold storage

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companies. Until recent years, due to limited apple production and storage of relatively small amounts, that have not played any significant impact on growers/storage company's incomes. However, from now on and in the future, when the apple production and their cold storage are expected to grow several fold, the optimization of all abovementioned factors are getting more importance.

In that context, the study was undertaken to determine the optimal harvest time of Korca area main apple cultivars according to contemporary methods, by following in same time their fruit weight progress.

### Materialidhemetoda

To monitor the maturity indices and fruit weight, three main apple cultivars of Korca are were selected: Golden Delicious, Red Chief dhe Granny Smith,grafted on MM 106 rootstock. The apple fruit samples were collected in three typical apple cultivation areas of the region, in an orchard of Dvoranplantation (approx. 5 km south of Korca city), Zvirine (approx. 19 km north of Korce city) and Vranisht (approx. 13 km northeast of Korce city). Based on simple randomization method, for each cultivar and orchard, 5 apple trees of mid age were selected, on MM 106 rootstock. Four apple fruits were picked up from each tree, one per each horizon directions (East, South, West, and North), in approx. 1.5 height from land level. That sample size provides a margin of error statistically accepted of 5%in the confidence level about mean, standard deviation and variation.

Apple fruits were picked and their maturity indexes and weight were analyzedin five different dates for Golden Delicious and Red Chief: on dates 13 September; 18 September; 23 September; 28 September and 3 October 2012. While for Granny Smith cultivar, in addition to those dates, another one on 8 October 2012.

The apple fruit indexes were:

- The Fruit firmness (F) in $kg/cm^2$, measured by a hand penetrometer (Wagner FT 30 brand) with a11 mm probe.
- The Total Soluble Solids (TSS) in Brix degree, measured by a hand refractmeter (ATC REF-114 brand).
- Starch Index (SI) through immersion for 30 sec. of half apples cut in their equatorial plan into a solution which contained 10gr dissolved crystals of Potassium Iodide (KI) and 2.5 Iodine (I) per liter of water. Estimation of starch conversion in simple sugars was made through the comparison of each half fruit with standard tables 1- 10, where 1 shows nil starch conversion, while 10 shows its 100% conversion.
- The Streif Index was calculated based on the abovementioned indexes, according to the following formulae:

$$Streif\ Index = \frac{Firmeness\ (F)}{Total\ Soluble\ Solids\ (TSS) \times Starch\ Index\ (SI)}$$

- The average apple fruits weight, through weighing each of them to a digital electronic scale 2 kg and precision level of 0.1 gr.
- The growth rate of fruit weight in relation to their maturity indices.

The calibration of penetrometer, refractometer and scale was made each sampling time, prior to make measurements. All data collected were analyzed by using Minitab 16 statistical Program, with a 95% confidence level.

### Results and discussion

Data collected about the fruit maturity indexes and weight for three apple cultivars under study showed that there were changing values of these indices from one to other picking time. The fruit's firmness was decreasing as their maturity progressed, while in the main time, the total soluble solids and starch index were increasing, along with fruit weight. Based on maturity index figures was calculated the Streif Index for each cultivar. Regarding this index,

there are differences between cultivars.The results of processing data with statistical method One-Way-Anova showed, that the maturity indices of each cultivar and respective picking up date do not have significant differences between fruits in any of three plantations, as always the values of P>0.05 (0.05 represents the  -level).

On the other side, there are differences in the average weight of fruits among orchards for same cultivar.Average values of maturity indices and fruit weight for every orchard and apple cultivar are shown in Table 1, Table 2 and Table 3.

<u>Golden Delicious</u>

The maturity indices of Golden Delicious cultivar, as shown in Table 1, have a significant difference form one picking date to the other. The fruit firmness was decreased by an average of 1.47 kg/cm$^2$in 20 days, or 0.074 kg/cm$^2$/day. The total soluble solids were increased to an average of1.82$^o$ Briks in 20 days, or 0.091$^o$ Briks/day, while the starch index was increased by 4.6 in 20 days, or 0.23/day.

Based on those three figures,the Streif Index was calculated, and its figures are shown for each of five picking dates in Table 1. This Index had its maximum value on 13 September (0.21), while on 3 October, the lowest one (0.06).

| Picking dates (2012) | Golden Delicious | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Mean of maturity indices for three orchards | | | | Apples mean weight (g) | | | |
| | Firmness (kg/cm$^2$) | Total Soluble Solids ($^o$Briks) | Starch Index (1 - 10) | Streif Index | Dvoran (1) | Vranisht (2) | Zvirinë (3) | Mean (1-3) |
| 13 Sept. | 7.72 | 12.95 | 2.88 | 0.21 | 157 | 153 | 142 | 150.7 |
| 18 Sept. | 7.32 | 13.47 | 4.08 | 0.13 | 176 | 171 | 157 | 168.0 |
| 23 Sept. | 6.91 | 13.93 | 5.40 | 0.09 | 191 | 185 | 172 | 182.7 |
| 28 Sept. | 6.56 | 14.36 | 6.50 | 0.07 | 196 | 190 | 177 | 187.7 |
| 3 Oct. | 6.25 | 14.77 | 7.48 | 0.06 | 198 | 192 | 179 | 189.7 |

Table 1

According to literature, it is recommended that the optimum harvest date for long term cold storage of Golden Delicious apples is when the Streif Index reaches a 0.1 value. However, as such a value may corresponds to only one day, which makes already impossible to harvest big orchards with that cultivar in such a short term, it was advised to start and complete harvesting as soon as possible, just in a couple of days before and after that optimum date. In regard to Starch Index value, it is adviced to be less than 6. Referring to data of Table 1, results that the optimal date for harvesting Golden Delicious was 20 September 2012 (Streif Index value 0.1) for three orchards. Table 1 shows as well the average fruit weight for each orchard on the picking dates, and the average of three orchards.  For apples picked on 13 September, thefruits of highest weights were those of Dvoran orchard (157 g/fruit), followed by those of Vranisht(153 g/fruit), while Zvirine orchard had the smallest ones (142 g/fruit). On October 3, the fruit weight per orchard were respectively 198g; 192g and 179g/fruit.

Table 1.1 shows that the fruit weight growth rate for from first to last picking for each orchard was approx. 26%. In the first picking Dvoranorchard fruits have an average weight of 4 g higher compare to those of Vranisht and 15 g of Zvirine, while in the last picking, such difference was increased respectively to 6g and 19 g. This related to the number of cells in each fruit. It was found that larger fruits have higher growth rates than smaller fruits due to their higher number of cells, although each cell may grow the same amount per day in all fruits (Lakso&Goffinet, 2013).

| Picking dates | Golden Delicious | | |
| --- | --- | --- | --- |
| | Dvoran | Vranisht | Zvirinë |

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| (2012) | Weight (g) | Growth (%) | Weight (g) | Growth (%) | Weight (g) | Growth (%) |
|---|---|---|---|---|---|---|
| 13 Sept. | 157 | - | 153 | - | 142 | - |
| 18 Sept. | 176 | 12.0 | 171 | 11.7 | 157 | 10.6 |
| 23 Sept. | 191 | 8.6 | 185 | 8.2 | 172 | 9.5 |
| 28 Sept. | 196 | 2.7 | 190 | 2.7 | 178 | 2.9 |
| 3 Oct. | 198 | 1.0 | 192 | 1.0 | 179 | 1.1 |
| Difference | 41 g | 26.1% | 39 g | 25.5% | 37 g | 26% |

Table 1.1

Based on the mean fruit weights of three orchards, it results that the decade 13-23 September had the highest weight increase rate of fruit, approx. 3 g/day, while in the five-day period 23–28September, it was only 1 g/day. The other five-day 28 September -3October, fruit weight was increased by 0.35g/day. The decrease of fruit growth rate after 23 September 23 was directly related to advances in the process of fruit maturity, by the end of which, the fruit growth stops (Lakso*et al*., 1995).
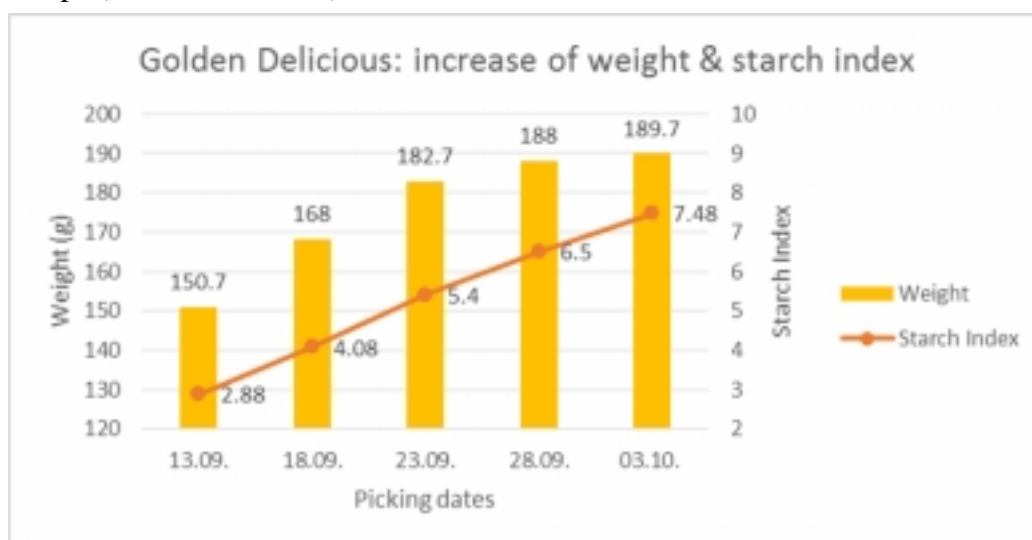


Graph 1

In Graph 1 is shown the fruit weight growth and the Starch Index for Golden Delicious. As starch conversion to simple sugars progress with dates, the fruit weight growth rate decreased.


Red Chief

TheRed Chiefcultivar, as data shown in Table 2, the fruit firmness was decreased by an average of 1.7 kg/cm$^2$ in 20 dys, or 0.085 kg/cm$^2$/day, while for the same period, the total soluble solids were increased by 2.9$^o$Briks, or 0.145$^o$Briks/day, and the starch index was increased by 4, or 0.2/day. The Streif Index values have followed a decrease, from 0.25 on 13 September to0.07 on3 October. According to literature recommendations, the optimal harvest date of Red Chief for long cold storage should be when Streif Index has a valued of 0.12. This figure corresponds to 20 September 2012 for three orchards.

| Picking up dates (2012) | Red Chief | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean of maturity indices for three orchards | | | | Apples mean weight(g) | | | |
| | Firmness (kg/cm$^2$) | Total Soluble Solids ($^o$Briks) | Starch Index (1 -10) | Streif Index | Dvoran (1) | Vranisht (2) | Zvirinë (3) | Mean (1-3) |
| 13 Sept. | 8.12 | 10.43 | 3.10 | 0.25 | 168 | 163 | 155 | 162.0 |
| 18 Sept. | 7.71 | 11.23 | 4.32 | 0.16 | 186 | 180 | 169 | 178.3 |
| 23 Sept. | 7.28 | 11.99 | 5.35 | 0.11 | 197 | 189 | 177 | 187.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28 Sept. | 6.84 | 12.68 | 6.32 | 0.08 | 200 | 191 | 179 | 190.0 |
| 3 Oct. | 6.41 | 13.33 | 7.13 | 0.07 | 201 | 191 | 178 | 190.0 |

Table 2

Table 2 shows the fruit mean weight in their picking days for each orchard and the mean of three orchards. On 13 September, the Dvoran orchard had the fruits of highest weight (168 g/fruit), followed by Vranisht (163 g/fruit) and Zvirine (155 g/fruit). In the last sample picking of October 3, Dvoranhad again the heaviest fruits, 201 g each, while Vranisht 191 g and Zvirine 178 g. The increase of weight was higher during the decade 13 – 23 September, with an average of 2.5 g/day while during the 5 days 23 – 28 September, the average increase was only 2.3 g, or 0.46 g/day. In the last five days 28 September– 3 October, the fruit weight was ceased, and in Zvirine fruit have lost 1 g. The decline of fruits weight growth rate for this cultivar after 23 September, was related to their maturity advancementas well.

Fruits of Dvoran orchard increased the difference in weight compare to Vranisht and Zvirine orchards from the first picking to the last one (Table 2.1). In the first picking their average difference was 5g compare to Vranisht and 13 g to Zvirine, while in the last picking it was 10g and 23 g respectively.

| Picking dates (2012) | Red Chief | | | | | |
|---|---|---|---|---|---|---|
| | Dvoran | | Vranisht | | Zvirinë | |
| | Weight (g) | Growth % | Weight (g) | Growth % | Weight (g) | Growth (%) |
| 13 Sept. | 168 | - | 163 | - | 155 | - |
| 18 Sept. | 186 | 10.71 | 180 | 10.43 | 169 | 9.03 |
| 23 Sept. | 197 | 5.91 | 189 | 5.00 | 177 | 4.73 |
| 28 Sept. | 200 | 1.52 | 191 | 1.05 | 179 | 1.12 |
| 3 Oct. | 201 | 0.00 | 191 | 1.03 | 178 | 0.00 |
| Difference | 33 g | 19.6% | 28 g | 17.1% | 23 g | 14.8% |

Table 2.1

The Graph 2 shows the weight and Starch Index for Red Chief in five different picking dates. The weight rate was decreasing after 23 September, while the Starch Index increasing.



Graph 2

If the fruits of this cultivar would be harvest on 20 September, which was the optimal date for long term cold storage, their average starch conversion to simple sugars would be 4.8

### Granny Smith

For the fruits of Granny Smith cultivar, as data shown in Table 3, the firmness was decreased with an average of 1.46 kg/cm$^2$in 25 days, or 0.058 kg/cm$^2$/day. The total soluble solids were

increased by me 2.52$^o$ Brix in 25 days, or 0.10$^o$ Brix/day, while the Starch Index was increased by 3.93 in 25 days, or 0.157/day. Measurements of these three maturity indices showed that Granny Smithfruits had the highest fruit firmness and the lowest total soluble solids and starch index compare to Golden Delicious and Red Chief fruits from the first fruit picking to the last one. Even more, the respective decrease/increase rate of any maturity indices of Granny Smithwas the lowest onecompare to two other cultivars. The Streif Index value was 0.85 on 13 September, while it came down to 0.13 on 8 October. Granny Smith is a late-harvesting cultivar with maturity indices that change very slowly, by offering to growers the opportunity for a longer harvesting period than two other cultivars, which may last for even more than two weeks (Kupferman, 1992). It's advises to start harvest for storage when Total Soluble Solids reach 12$^0$Brix, while Streif Index is more than 0.15, which corresponds date 4 October 2012.

Table 3 shows as well the means of fruit weights of Granny Smith in each of three orchards and their average for each picking date. During the 25 days period from the first to the last picking, theaverage fruit weightwas increased63.6 g or 2.54 g/day. The most intensive weight growth rate was from 13 – 28 September, with an average of 3.3 g/day/fruit. That was decreased to 2g/day in the five-day period 28 September – 3October, while from 3 – 8 October  was 3.6 g or 0.72 g/day.

| Picking dates (2012) | Granny Smith | | | | | | | |
| | Mean of maturityindices for three orchards | | | | Apples mean weight(g) | | | |
| | Firmness (kg/cm$^2$) | Total Soluble Solids ($^o$Briks) | Starch Index (1 – 10) | Streif Index | Dvoran (1) | Vranisht (2) | Zvirinë (3) | Mean (1-3) |
|---|---|---|---|---|---|---|---|---|
| 13 Sept. | 9.35 | 9.37 | 1.18 | 0.87 | 152 | 147 | 138 | 145.7 |
| 18 Sept. | 9.07 | 9.87 | 2.10 | 0.44 | 170 | 164 | 153 | 162.3 |
| 23 Sept. | 8.76 | 10.44 | 2.93 | 0.29 | 188 | 182 | 169 | 179.7 |
| 28 Sept. | 8.49 | 10.96 | 2.72 | 0.21 | 204 | 198 | 184 | 195.7 |
| 3 Oct. | 8.18 | 11.47 | 4.48 | 0.16 | 215 | 208 | 194 | 205.7 |
| 8 Oct. | 7.89 | 11.88 | 5.12 | 0.13 | 220 | 211 | 197 | 209.3 |

Table 3

Among fruits picked on 13 September, those of Dvoran orchard had the average highest weight (152g/fruit), or 5 g more than Vranisht and 14 g more than Zvirine. Such a difference was increased continuously until the last picking on8 October, to respectively 9 g and 23 g (Table 3.1).

| Picking dates (2012) | Granny Smith cv. | | | | | |
| | Dvoran | | Vranisht | | Zvirinë | |
| | Weight (g) | Growth % | Weight (g) | Growth % | Weight (g) | Growth (%) |
|---|---|---|---|---|---|---|
| 13 Sept. | 152 | - | 147 | - | 138 | - |
| 18 Sept. | 170 | 11.8 | 164 | 11.6 | 153 | 10.9 |
| 23 Sept. | 188 | 10.6 | 182 | 10.9 | 169 | 10.5 |
| 28 Sept. | 204 | 8.5 | 198 | 8.8 | 184 | 8.9 |
| 3 Oct. | 215 | 5.4 | 208 | 5.1 | 194 | 5.4 |
| 8 Oct. | 220 | 2.3 | 211 | 1.4 | 197 | 1.5 |
| Difference | 68 g | 44.7% | 64 g | 43.5% | 59 g | 42.7% |

Table 3.1

Graph 3 shows the average of increase of fruit weight and the Starch Index from the first to the sixth picking date. There was a linear growth curve of fruit weight from the first to fourth picking and afterwards a decline, while forstarch index the lineargrowth continued until the last sixth picking.

Graph 3

By comparing figures from tables and graphs, it results that Granny Smith has very different advancements in fruit maturity indices and weight growth rate than Golden Delicious and Red Chief.

**Conclusions**

Data collectedshowed that for each of three apple cultivarsin this study, the respective fruit maturity indices have very slight, non-significant differences from one orchard to the other. Consequently, even the Streif Index figures were very same, which means that the optimal harvest dateswere reached same day of year for each cultivar, despite the orchard location.

- For Golden Delicious and Red Chief resulted as 20 September 2012 was the optimal harvest date for long term storage has been (Streif Index 0.1 and 0.12 respectively). Growers should concentrate their efforts to harvest these two cultivars as soon as possible, within a couple of days prior and after the optimal date.

- For Granny Smith, 4 October 2012 was the first day to start harvesting and complete it for longer period than two other cultivars, based on advancement of maturity indices.

- The fruit weight growth rate has been higher for Golden Delicious and Red Chief during the period 13 – 23 September, with arespective average of 3.2 g/day/fruit for the first one and 2.5 g/day/fruit for the second. The growth was significantly reduced for both cultivars during the five-day period 23 – 28 September, and it was already ceased in the next five-day 28 September – 3 October.

- The late harvest cultivar Granny Smith had a higher linear increase fruit weight during 13 – 28 September ofan average 3.3g/day, which was decreased in 2 g/day in the next five-day, and in the last one, 3 – 8 October it went down to 0.72 g/day.

- Dvorani orchard fruits of three cultivars had the highest average weight from the first to last picking. The difference in fruit weight of this orchard compare to two other ones was increased from the first to last picking, following very similarly the literature findings, which showed that increase in weight depends more in the total number of fruit cells, as they may follow same weigh growth. Operations like fruit thinning are important, as they enable a larger number of cells for each fruit and a better distribution of nutrition elements and water to them.

- There were slight weight differences of Golden Delicious and Red Chief if harvested on 20 September compare to 3 October. However, literature examples shows that are not significant to growers income, if compared to apple quality after long cold storage refrigeration. In order to maximize incomes, growers should harvest apple cultivars

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accordingly to their destination, by determining first the optimal harvest dates for cold storage. More mature fruits should be sold for short storage and/or instant consumption.

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