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Influence of rain cover on respiration, quality attributes and storage of cherries (*Prunus avium* L.)

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Summary

The effects of rain cover on tree yield, fruit cracking and quality of two cherry (*Prunus avium* L.) cultivars, 'Adriana' and 'Noire de Meched' ('NM'), were investigated. Cherry quality was determined at harvest and after storage at 1 ºC in air for up to 21 d. Rates of CO_2 production and O_2 uptake were determined at weekly intervals during and after storage. A taste panel rated quality attributes of 'NM' after 14 d storage. The results showed that 'Adriana' was completely, but 'NM' moderately resistant to cracking, while covering prevented the symptom. Respiration rates showed immediate and continuous cooling requirements of all fruit. In 'Adriana', covering reduced weight loss during the first 7-d storage, and promoted the peel colour (PC) and total soluble solids subsequently. Under different environmental conditions, PC and total phenolics were advanced in uncovered 'NM' at harvest and after storage. In both cultivars, covering did not affect negatively the yield, nor did it significantly the fruit weight, firmness, titratable acidity, pH value, total antioxidant activity, stem browning and resistance to stem removal. 'Adriana' and 'NM' retained good quality for 21 and 14 d storage, respectively.

Introduction

Sweet cherries are very popular fruit and the first fresh temperate ones of the year with a high economical impact in cherry-producing countries. Additionally, there has been an increasing consumption of fresh cherries due to consumer awareness of their benefits on health (McCune et al., 2011). These effects are mainly attributed to their content of phenolic antioxidants (Kris-Etherton et al., 2002), serotonin and melatotin (Gonzales-Gomez et al., 2009). However, fresh cherries are exposed to the market for a relatively short period of time, while they cannot be stored for longer than few weeks. Besides, they are susceptible during transport. Additionally, the cherry cultivation has a major problem, the fruit cracking, due to the rapid increase in water absorption either through the fruit skin or the root system, both occurring after rainfall (Balbontin et al., 2013). Cracking susceptibility increases with advanced maturation. It also depends on many cultivar characteristics, rootstock, fruit set, amount of rainfall, and other factors (Measham et al., 2009; Measham et al., 2014; Simon, 2006). Under unfavourable conditions cracking could result in a great loss of production, reaching up to 90% (Christensen, 1996), while cracked cherries are used only for processing provided that they are not affected by fungus (Simon, 2006). Reduction of the problem includes the establishment of plastic sheets that cover the tree canopy (rain cover) for at least three weeks before harvest (Meland et al., 2014), preharvest sprays with hydrophobic and other compounds or other practices (Balbontin et al., 2013; Meland et al., 2014). None of the treatments can eliminate or even guarantee the result. However, the most effective treatment seemed to be the expensive technique of tree covering. Rain cover has been studied mainly in Northern Europe, but changes in microclimate under cover exhibited inconsistent effects on delayed or advanced ripening (Borve et al., 2003).

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The aim of this work was to use a kind of typical rain covers in order to investigate their interactive effect (temperature, humidity, solar radiation) on cracking, as well as quality attributes in undamaged cherries in two less studied cultivars. The selected cultivars were 'Adriana' and 'Noire de Meched', being one mid-early and one mid ripening, respectively. There is not much information in the literature concerning quality characteristics of these cultivars in comparison to many others. Resistance to cracking is among the main targets for cherry cultivation. 'Adriana' originates from Italy and is described as resistant to cracking, while 'Noire de Meched' originates from Iran, belongs to Ferrovia group (Sansavini and Lugli, 2008) and also showed a high cracking resistance (Greco et al., 2008). On the contrary, according to Vercammen and Vanrykel (2014) 'Noire de Meched' showed moderate susceptibility to this symptom. Thus, there is a global tendency to evaluate the less studied cherry cultivars *in situ* (Balbontin et al., 2013). The present evaluation was carried out on fruit from trees grown in Northern Greece, the major cherry cultivation area in Greece, where rainfall still remains a serious problem. The tree yield was also determined since the trees were relatively young with increasing yield that is usually inversely related to fruit size. Fruit size in turn could affect the cracking percentage. In contrast to the principle that storage is not applied to early cultivars the present study kept the fruit under low temperature in order to cover the time required for the fruit to reach the consumer at distant markets and to get the opportunity to examine the quality changes in detail. Emphasis was given on respiration rates since they reflect on the rate of quality deterioration and therefore of cooling requirements and storability.

Materials and methods

Source and handling of fruit

Experiments were conducted in Macedonia, Greece on a property located approximately 52 m above the sea (lat. 40º 41' N; long. 22º 9' E). Rain cover was used on cherry trees (*Prunus avium* L.) of the cultivars 'Adriana' and 'Noire de Meched'. All trees were grafted on Gisela 5 rootstock, planted at distances of 3.5 m x 1.5 m apart in 2006 and trained as palmette. Trees were permanently covered by a white high density polyethylene film of light transparency equal to or greater than 85% (Helios, Italy) for approximately three weeks before harvest. Uncovered trees served as controls. The rain covering system resembled to the three-wire one (Meland et al., 2014). The construction had a frame of wooden poles spaced at 10 meters apart and three overhead wires running the length of the row. The side wires were positioned up to 0.5 m lower than the top wire. The top of the tree was kept at a distance of 0.5 m from the top wire in the begging of the season. The overhead covers could slide back and forth to open and close on three wires down the row and were removed after harvest. The yield and fruit cracking percentage for each treatment (covered or uncovered trees) were estimated at harvest from 2 replicates of 7 trees each in the case of 'Adriana' and from 3 replicates of 5 trees each in the case of 'Noire de Meched'. The yield and cracking were measured in both cultivars in two experimental years, 2009 and 2011. Fruit of 'Adriana' in 2009 and 'Noire

de Meched' in 2011, without cracking at harvest, selected at random from 3 replicates of 5 trees each from both treated and controls and were transferred to the laboratory.

Upon arrival, fruit from each treatment were mixed and then divided into three lots. For each treatment, cherries attached to stems and free from visual defects were sorted out at random and placed in pots in groups of ten each. Then, the pots were placed at 1 ºC with 95% RH, according to a completely randomised design. Respiration was measured either at 1 ºC or at 20 ºC, as denoted, while all the rest determinations at 20 ºC after temperature equilibration. On each sampling day, for each treatment and at each temperature, further determinations were carried out on fruit of three pots (three replicates), apart from 10-fruit weight that evaluated on twelve pots. First samples were collected at random prior to storage at 1 ºC and corresponded to samples after harvest (day 0 of storage).

Determinations on fresh fruit

Weight loss

Before storage the initial weights of all fruit samples were recorded, while on each sampling date the weights of three samples per treatment were recorded after temperature equilibration at 20 ºC.

Respiration rates

On each sampling day, respiration gases were measured on the same replicates. Measurements were carried out according to Tsantili et al. (2003) after some modifications. In particular, headspace CO_2 and O_2 were analysed by the same injection of 0.5 ml in a gas chromatograph (Hewlett Packard 5390 Series II) with a thermal conductivity detector and He as the carrier gas at a flow rate of 0.33 ml s^{-1}. The instrument was equipped with two successive columns, one of Porapaq Q (50-80 M) for CO_2 and one of Molecular Sieve (40-60 M) for O_2, both of 300 cm x 0.2 cm i.d. A commercial standard consisted of 2% CO_2 and 2% O_2 in N_2 was used for instrument calibration and a laboratory computing integrator (Hewlett Packard 3395) for results calculation. Gas samples were taken from 0.5 l sealed jars after 1 h incubation. Results are expressed in nmol kg^{-1} s^{-1} at the corresponding temperature, while respiration quotient (RQ) and Q_{10} (for O_2, between 0 ºC and 20 ºC) were calculated.

Peel colour

Peel colour was measured on the two opposite sides of each fruit with a Minolta chromatometer (CR-300; Minolta, Ahrensburg, Germany) according to Tsantili et al. (2007) and expressed in L^*, h^o and C^*.

Stem browning

Stem browning (SB) was measured visually. Stems were divided into four classes, depending on their length with brownish colour: no brown corresponded to 4/4 green; slightly brown, ≤ 1/4 brownish; low brown, 1/4 - 1/2 brownish; brown, > ½ brownish.

Resistance to stem removal

Resistance to stem removal (RSR) was measured by a Chatillon traction-penetrometer (J. Chatillon and Sons Inc.) with a scale of 0-1.0 kg (± 0.01) and according to Tsantili et al. (2007). Results are presented in Newtons (N) after division into four classes: 0-3 N, 3-6 N, 6-9 N and > 9 N.

Fruit firmness

Fruit firmness was measured according to Tsantili et al. (2007). It was recorded as the peak force to penetrate one side of unpeeled fruit using a conical probe of 5 mm diameter x 5 mm height, mounted on a bench Chatillon DF1S 50 penetrometer (J. Chatillon and Sons Inc., New York, USA). The speed of the probe was at 0.42 mm s^{-1}.

Total soluble solids

Total soluble solids (TSS) of flesh was estimated in each fruit separately by an Atago 8469 (Atago Co. Ltd., Tokyo, Japan) hand refractometer.

pH

pH was measured by a pH-meter (Jenway 3310; Jenway Ltd., Dunmow, UK).

Titratable acidity

Titratable acidity (TA) was measured by titration of 10 g sap from unpeeled fruit to pH 8.2 with 0.1 M NaOH.

Extraction of phytochemicals

The extraction procedure and determinations of total phenolics (TP) and total antioxidant activity (TAA) were carried out according to Tsantili et al. (2010) after some modifications. Slices of 10 fruit were placed immediately at -80 ºC after sampling. Frozen tissue of approximately 10 g was homogenised with cold 80% acetone (v/v) in deionised water (4 l kg^{-1} tissue) using an Ultra-Turrax (T 25, Ika Labortechnik, Germany). The homogenate was placed in an ultra sonic ice bath for 15 min and then filtered in the dark through # 1 Whatman paper. The residue was filtered twice with 15 ml of acetone (80%), while the whole procedure was conducted at 4 ºC. Then the filtrate was recovered at 38 ºC under N_2, brought to 30 ml with water and kept at -80 ºC until analysis.

Determination of total phenolics

The TP concentration was determined by the Folin-Ciocalteu method (Singleton et al., 1999). In particular, 0.2 ml of diluted extract was added into a tube containing 0.2 ml of Folin-Ciocalteu reagent and 2.6 ml of deionised water. After stirring, the tube was allowed to stand at 20 ºC for 6 min. Then, 2 ml of Na_2CO_3 (7%, w/v) were added, the tube was incubated at 20 ºC for 90 min. Absorbance was measured at 750 nm with a spectrophotometer (Helios Gamma 7 Delta, Spectronic Unicam, UK) versus a blank. The results were expressed as gallic acid equivalents (GAE) on a fresh weight basis and according to the corresponding calibration curves.

Determination of total antioxidant activity

The TAA was determined according to DPPH (Brand-Williams et al., 1995). Diluted extract (with deionised water) of 0.1 ml was added into a tube containing 3.9 ml DPPH solution (2,2-diphenyl-1-picryhydrazyl, 60 μM in MeOH). Absorbance decrease was measured at 515 nm after incubation in the dark at 20 ºC for 30 min versus a blank. The results were expressed as mmol of trolox (6-hydroxy-2,5,7,8-tetramethlchroman-2-carboxylic acid) equivalents (TE) on a fresh weight basis and according to the corresponding calibration curves.

Sensory evaluation

The panel consisted of 14 people (7 men and 7 women, aged 20-58), all untrained, but familiar with cherries consumption. To avoid any bias, a minimum of information was given. Each panelist individually evaluated two groups of 10 cherries each, uncovered and rain-covered, in succession. The groups were blind labelled with 4 digit codes randomly. During the evaluation each panelist had a glass of room temperature water to rinse his palate. For each evaluated characteristic the rating was based on a three-point scale (1: low inten-

sity; 2: medium intensity; 3: high intensity). The evaluated attributes were: size, peel colour, flesh colour, stem browning, texture (firmness), resistance to stem removal (RSR), easiness of stone removal, sweetness, sourness, overall taste and overall acceptance.

Statistical analysis

The covering effect at harvest, the year effect and their interaction on yield and fruit cracking percentage were estimated by a two-way analysis of variance. Where denoted, some means are followed by their standard error. The effects of covering, storage days at 1 ºC and their interaction on weight loss (WL), colour parameters, firmness, TSS, TA, TSS/RTA, pH, TP and TAA, as well as, on respiration (CO_2 production rates, O_2 uptake and RQ) at each temperature were analyzed by a two-way factorial analysis of variance. The effect of temperature, covering, storage days at 1 ºC and their interactions on respiration data were also analyzed by a three-way analysis of variance after excluding data at harvest. When needed, data were properly transformed to meet the assumptions of normality and homoscedacity. Presented data are back transformed. Comparison of means between the above variables was based on LSD (a = 0.05). Data for SB and RSR were evaluated by c^2 tests. The effect of covering on weight of fruit, seeds and stems, and on each characteristic evaluated by the taste panel was statistically estimated by two-sample comparisons (independent samples). The statistical analyses were made using JMP 7.0.1. (SAS Institute, Cary, NC, USA).

Results and discussion

Tree yield and fruit cracking

In the particular orchard, the commercially estimated harvest season for 'Adriana' ranged between 1 June and 13 June, while for 'Noire de Meched' between 9 June and 19 June. In the present study, yield and cracking in 'Adriana' were estimated on 1 June, 2009 and 10 June, 2011 and in 'Noire de Meched' on 10 June, 2009 and 15 June, 2011 (Tab. 1). The yield averaged approximately 20.1 kg per tree in 'Adriana' and approximately 17.6 kg in 'Noire de Meched', in 2009 (Tab. 1). Covering did not affect the yield in 'Noire de Meched', whereas increased the yield in 'Adriana', but only in 2009 and at the limits of significance. SOTIROPOULOS et al. (2014) found that covering protected all four studied cultivars from cracking in a three-year study without decreasing the productivity of trees trained to the open vase system. In 2011, here, the presented averaged yield in both covered and uncovered trees increased by approximately 1.7- fold and 2.3-fold in 'Adriana' and 'Noire de Meched', respectively. However, the yield increase was expected during growing of the relatively young trees.

Cracking was not practically observed in 'Adriana'. In contrast, 'Noire de Meched' showed similar cracking levels in both studied years in the uncovered trees, reaching approximately 20%, in average (Tab. 1). Covering exhibited a great beneficial effect on 'Noire de Meched', eliminating cracking in 2009 and reduced it largely to 3% in 2011. Precipitation, during the last 22 days before harvest of 'Adriana' and 'Noire de Meched', reached 68 mm and 62 mm, respectively, in 2009, while 63 mm and 31 mm, respectively, in 2011. The observed cracking in this study was of stem-end type, as described by SIMON (2006). The present results agreed with other studies in the case of 'Adriana' (GRECO et al., 2008; SANSAVINI and LUGLI, 2008). However, in 'Noire de Meched', the present results agreed with those suggested by VERCAMMEN and VANRYKEL (2014), but not with those by GRECO et al. (2008) who found an almost immune behaviour of this cultivar to cracking. The disagreement between studies could be ascribed, at least partially, to the variation of the symptom among years in relation to weather conditions and/or cultivation practices.

According to LANE et al. (2000) the threshold of absorbed water at which cracking starts is connected to cracking susceptibility. However, there is no apparent relation of cracking susceptibility to stomata number (CHRISTENSEN, 1972) and pore areas per stomata (as one of the factors that could influence water absorption) since stomata were not functional during ripening (PESCHEL et al., 2003). Interestingly, the last research group found that 'Adriana' had the smallest number of stomata per fruit and pore area in cheek region among eight studied cultivars. Research approaches, such as gene

Tab. 1: Effects of rain cover on tree yield and fruit cracking (%) in 'Adriana' and 'Noire de Meched', in 2009 and 2011.

	Cultivar							
	'Adriana'				'Noire de Meched'			
	Orchard (Uncovered or OR)		Rain Covered Orchard (RC)		Orchard (Uncovered or OR)		Rain Covered Orchard (RC)	
Attribute	1/6/2009	10/6/2011	1/6/2009	10/6/2011	10/6/2009	15/6/2011	10/6/2009	15/6/2011
Yield (kg per tree)	19.59	31.59	20.76	32.10	18.1	41.1	17.2	40.23
n	2 (x 7)				3 (x 5)			
$LSD_{(0.05)}$[a]	0.89				4.56			
Ptr[b]	*				ns			
Py	***				***			
Ptr x y	ns				ns			
Cracking (%)	1.9	2.3	0.9	2.8	17.7	23.3	0.11	3.4
n	2 (x 7)				3 (x 5)			
$LSD_{(0.05)}$	2.1				5.4			
Ptr	ns				***			
Py	ns				ns			
Ptr x y	ns				ns			

[a] $LSD_{(0.05)}$, Least Significant Difference at a = 0.05.
[b] *Ptr*, covering treatment; *Py*, year; *x*, interaction.
ns, not significant.
*, significant at $P < 0.05$.
***, significant at $P < 0.001$.

expression of expansins and of the enzyme β-galactosidase that are related to cell wall extension in cultivars with different cracking susceptibility seemed to be promising to investigate the mechanisms of cherry cracking (Balbontin et al., 2013).

Respiration

In 'Adriana', covering exhibited no effect on respiration gases (Fig. 1) after harvest, as also confirmed by two-sample comparisons. In particular, the rates of CO_2 production were approximately 278 nmol kg^{-1} s^{-1} and 361 nmol kg^{-1} s^{-1} in controls and covered fruit, respectively, while those of O_2 uptake were 11.1 nmol kg^{-1} s^{-1} and 361 nmol kg^{-1} s^{-1}, respectively (Fig. 1A and C). During keeping fruit at 1 ºC, both respiration rates decreased dramatically, being by 6-fold lower on day 7 than at harvest, in average, and remained at similarly low levels up to day 14. Under the lower temperature, there were significant, but small increases in both gases in uncovered fruit on day 21 (Tab. 2). After storage, 'Adriana' showed similar trend of changes between covered and uncovered fruit for respiration rates of both gases at 20 ºC. The reduction of CO_2 production at 20 ºC in covered fruit on day 7 and the increase in CO_2 in controls on day 21 were the only significant changes in comparison to fruit at harvest.

In 'Noire de Meched', the rates of CO_2 production and O_2 uptake in controls and treated fruit at harvest were between 250 nmol kg^{-1} s^{-1} and 278 nmol kg^{-1} s^{-1}, in average (Fig. 1B and D), while covering had no effect on them. At 1 ºC, the rates of both gases averaged by 5.1-fold lower on day 7 than at 20 ºC after harvest and remained almost stable up to the end of storage. After storage, however, the increased CO_2 production rates at 20 ºC were advanced by storage days in both controls and treated fruit, whereas O_2 uptake decreased in all fruit at 20 ºC on day 14. The significant effects of storage days and temperature, but not of covering on respiration gases in both cultivars are shown in Tab. 2. The present results are in general agreement with those of gas exchange rates measured at 0 ºC and 20 ºC (Wang and Long, 2014) or of CO_2 production rates at 20 ºC after storage at 0-1 ºC (Diaz-Mula et al., 2012; Tsantili et al., 2007). In the last study, inexplicable increases were observed at 20 ºC towards the end of storage, being similar to these results.

At harvest, RQ averaged 0.93 and 0.98 in 'Adriana' and 'Noire de Meched', respectively (Tab. 3). Covering did not show any significant effect on RQ at harvest on both cultivars (by two-sample comparisons) and on 'Adriana' cherries during or after storage. On the contrary, treatment resulted in increased RQ values in the covered 'Noire de Meched' fruit during and after storage in comparison to controls (Tab. 3). Significant increases were also observed progressively during and after storage, resulting in values of 1.06 and 1.37 in 'Adriana' and 'Noire de Meched', respectively, averaged for both temperatures at the end of the experiment. The higher temperature used reduced the RQ values in 'Adriana', but did not affect those

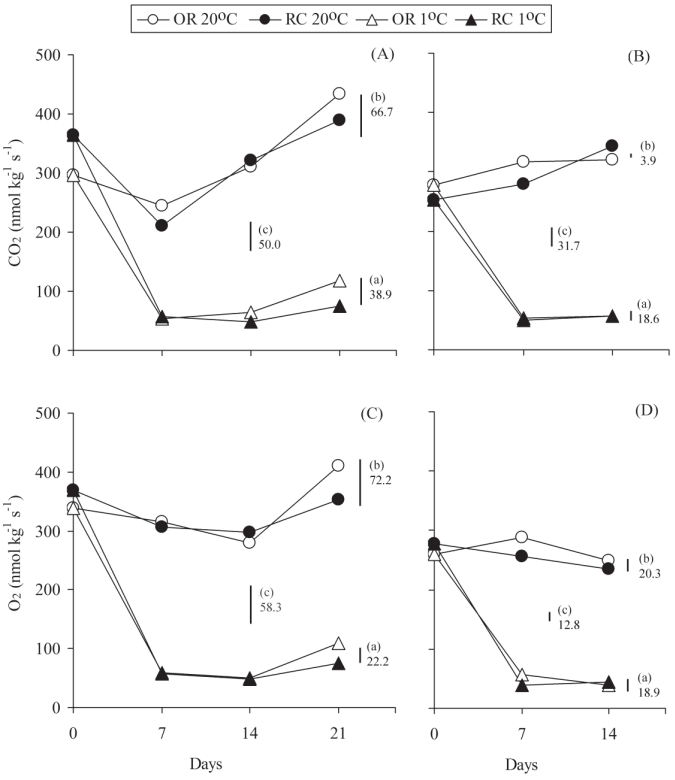

Fig. 1: Effects of rain cover on respiration rates in 'Adriana' in 2009 and 'Noire de Meched' cherries in 2011 before, during and after storage. (A) and (B), CO_2 production rates; (C) and (D), O_2 uptake rates; (A) and (C), 'Adriana'; (B) and (D), 'Noire de Meched'. OR, Orchard Uncovered; RC, Rain Covered Orchard. Vertical bars correspond to LSD at a = 0.05. (a) bars, 1 ºC, including data at harvest; (b) bars, 20 ºC, including data at harvest; (c) bars, all data apart from those at harvest.

Tab. 2: Probabilities of the effects of rain cover treatment (*Ptr*), storage time (*Pst*), temperature (*Pte*) and their interactions on CO_2 production and O_2 uptake rates and on RQ in 'Adriana' and 'Noire de Meched' cherries at harvest at 20 ºC, during storage at 1 ºC and after storage at 20 ºC.

Cultivar	Temperature (ºC)		Probabilities[a]		
			Attribute		
			CO_2	O_2	RQ
'Adriana'	1	*Ptr*	ns	ns	ns
		Pst	***	***	***
		Ptrxst	**	**	ns
	20	*Ptr*	ns	ns	ns
		Pst	***	**	***
		Ptrxst	ns	ns	ns
	1 & 20	*Ptr*	ns	ns	ns
		Pst	***	***	***
		Pte	***	***	**
		Ptrxst	ns	ns	ns
		Ptrxte	ns	ns	ns
		Pstxte	***	ns	*
		Ptrxstxte	ns	ns	ns
'Noire de Meched'	1	*Ptr*	ns	ns	ns
		Pst	***	***	***
		Ptrxst	ns	ns	**
	20	*Ptr*	ns	ns	ns
		Pst	***	**	***
		Ptrxst	ns	**	**
	1 & 20	*Ptr*	ns	ns	*
		Pst	*	***	***
		Pte	***	***	ns
		Ptrxst	*	**	ns
		Ptrxte	ns	*	ns
		Pstxte	ns	**	ns
		Ptrxstxte	ns	ns	**

[a] *Ptr*, covering treatment; *Pst*, storage time; *Pte*, temperature; *x*, interaction.
ns, not significant.
*, significant at $P < 0.05$.
**, significant at $P < 0.01$.
***, significant at $P < 0.001$.

in 'Noire de Meched' (Tab. 3). WANG and LONG (2014) found the RQ to be almost constant when measured at 0 ºC, 10 ºC and 20 ºC after harvest, with all values being between 0.60 and 0.70 in 'Bing' and 'Sweetheart' cherries. Differences in RQ could be attributed to different cultivars, maturity state at harvest and experimental conditions. In the case of 'Noire de Meched', the highly increased RQ values to approximately 1.37 after 14 d storage (at both 1 ºC and 20 ºC, in average) is of interest and could be largely attributed to oxidation of organic acids (BEAUDRY et al., 1992) and mainly of malate (TSANTILI et al., 2007; USENIK et al., 2008). By contrast, RQ values equal to 1 indicated the sugars as respiration substrates, while lower than 1 the lipids (FONSECA et al., 2002).

The present study also calculated the Q_{10} values from rates of O_2 uptake since O_2 is less soluble in fruit sap than CO_2. On day 7, the averaged Q_{10} values (rate of O_2 at 20 ºC/rate of O_2 at 1 ºC) were 2.8 and 3.0 for 'Adriana' and 'Noire de Meched', respectively. These values are relatively high and denoted the necessity of keeping the fruit at low temperature, as also suggested by WANG and LONG (2014) for similar Q_{10} values calculated from CO_2 production rates measured after harvest.

Objective measurements of quality attributes of fruit

In 'Adriana' controls and treated fruit with cover, the initial values of fruit weight, colour parameter *C**, firmness, TA, TSS/TA, pH, TP and TAA averaged approximately 8.5 g, 26.5, 4.0 N, 0.63 g kg^{-1}, 21.6, 3.97, 0.66 g kg^{-1} and 4.73 mmol kg^{-1}, respectively and they were not affected by the covering treatment after harvest (Tab. 4). Results showed that 'Adriana' cherries have a satisfactory fruit weight as a mid-early ripening cultivar (SANSAVINI and LUGLI, 2008), adequate firmness, but relatively high TA and low TSS at early harvest. In covered fruit, the value of the colour parameter h^o was slightly lower and of TSS higher than controls, indicating a tendency of earlier ripening that became significant, however, only after storage (Tab. 4). A clear effect of covering on earlier ripening was observed in some early ripening cultivars, due to the increased temperature in a completely enclosed tunnel (BALMER and BLANKE, 2008; SCHMITZ-EIBERGER and BLANKE, 2012). In this study, the meteorological data logging system, measuring at three positions from 7.00 am to 8.30 pm during the last 22 days before harvest, recorded some differences between the uncovered and covered orchard. In 2009, covering reduced the averaged mean of solar radiation from 391 W m^{-2} in controls to 360 W m^{-2} in covered fruit and relative humidity (RH) from 59.5% to 55.7%, whereas increased that of temperature from 24.4 ºC to 25.3 ºC and the averaged maximum temperature from 27.8 ºC to 29.8 ºC. Consequently, 'Adriana' is a cultivar practically resistant to cracking, at least in the studied area, with no need for covering.

In 'Adriana', storage increased the ratio of TSS/TA, TP concentration and TAA, lowered *L**, *C** and TA values, with the effects being significant, while had no effect on h^o, firmness and TSS in both controls and treated cherries (Tab. 4). The changes in TA resulted in fruit less acid and more agreeable than after harvest with a value of TSS/TA equal to or greater than 25 towards the end of storage. A value of TSS/TA greater than 25 is considered critical for eating quality (SCHMITZ-EIBERGER and BLANKE, 2012), but this contrasts the findings of KAPPEL et al. (1996) that the optimum TSS/TA should be 15-20. However, it is well known that consumer preference is influenced by many factors. Here, it is worth noting that when TSS/TA was greater than 25 the RQ value was the maximum observed and TA the lowest in the case of 'Adriana', implying that organic acids were the respiration substrates.

In covered and control 'Noire de Meched' fruit, the values of fruit weight averaged 12 g (per fruit) and of fruit seed 0.67 g (per seed) at harvest and there was no effect of covering on them (Tab. 5). The fruit weight of this cultivar, here, was, in agreement with that found by VERCAMMEN and VANRYKEL (2014) and much higher than in other study (USENIK et al., 2008). An averaged weight of 12 g is considered ideal for cherry fruit, according to KAPPEL et al. (1996). The different cultivation practices could influence these attributes to a great extent. In this work, firmness, TSS, TA, TSS/TA, and pH values in 'Noire de Meched 'averaged 3.62 N, 16.39 ºBrix, 0.79 g kg^{-1}, 20.68 and 3.53, respectively, in all fruit at harvest (Tab. 5). The values were independent of the covering treatment and storage apart from pH that increased gradually in stored fruit. The present results showed that 'Noire de Meched' had higher weight and TSS value and lower h^o and pH values than 'Adriana' at harvest, being more attractive by comparison. In 'Noire de Meched', h^o was the only colour parameter significantly reduced by covering and not by storage (Tab. 5). In 2011, however, the meteorological data system showed that covering reduced the averaged mean radiation from 268 W m^{-2} in controls to 227 W m^{-2} in covered fruit, whereas increased the corresponding relative humidity from 70.9% to 72.9%, and the temperature from 22.7 ºC to 23.3 ºC and the averaged maximum temperature from 26.3 ºC to 27 ºC during the last 22 days before harvest. It seems that when temperature difference between covered and uncovered fruit is small then other factors become more important to affect ripening attributes. Indeed, in 2011 the weather was cooler and cloudier than in 2009, and the higher solar radiation

Tab. 3: Effects of rain cover on respiratory quotient (RQ) values in Adriana' and 'Noire de Meched' cherries at harvest, during and after storage.

Cultivar	Temperature (ºC)	Treatment[a]	Storage days (d)				$LSD_{(0.05)}$[b]
			0	7	14	21	
Adriana (2009)	1	OR	0.88	0.92	1.31	1.07	0.20
		RC	0.98	0.82	1.33	1.03	
	20	OR	0.88	0.78	1.11	1.06	0.11
		RC	0.98	0.70	1.08	1.10	
	1 & 20	OR & RC	-				0.16
'Noire de Meched' (2011)	1	OR	1.05	0.95	1.40	-	0.19
		RC	0.91	1.25	1.33	-	
	20	OR	1.05	1.09	1.28	-	0.17
		RC	0.91	1.08	1.46	-	
	1 & 20	OR & RC	-				0.18

[a] OR, Orchard (Uncovered); RC, Rain Covered Orchard.
[b] LSD, Least Significant Difference at a = 0.05.

Tab. 4: Effects of rain cover on quality attributes in 'Adriana' cherries at harvest and after storage, in 2009.

	Treatment											
	Orchard (Uncovered or OR) Storage days (d)				Rain Covered Orchard (RC) Storage days (d)					Probabilities[c]		
Attribute	0	7	14	21	0	7	14	21	$LSD_{(0.05)}$[b]	*Ptr*	*Pst*	*PtrxPst*
Weight of 10 fruit (g)[a]	82.50	-	-	-	82.54	-	-	-	-	ns		
Weight loss (%)[a]	-	2.47	3.72	5.06	-	1.79	3.33	4.92	0.66	*	***	ns
*L**	32.73	33.30	32.45	31.22	32.44	31.53	31.73	30.86	1.28	*	*	ns
H°	16.6	16.79	15.19	13.23	15.15	13.58	14.13	12.4	2.50	*	ns	ns
C°	27	28.07	24.65	21.09	26.01	22.62	22.31	19.68	4.49	ns	**	ns
Firmness (N)	3.92	4.07	4.08	3.70	4.08	4.14	3.89	3.64	0.58	ns	ns	ns
TSS (°Brix)	13.40	13.06	13.51	13.56	13.93	14.13	14.43	14.13	0.57	***	ns	ns
TA (g kg^{-1})	0.65	0.58	0.59	0.48	0.61	0.61	0.57	0.52	0.06	ns	***	ns
TSS/TA	20.54	22.69	22.77	27.93	22.67	23.36	25.09	27.57	3.29	ns	***	ns
pH	4.01	3.79	3.95	4.05	3.94	3.84	3.92	4.00	0.09	ns	***	ns
TP (g kg^{-1})[d]	0.73	0.59	0.69	0.91	0.59	0.76	0.84	0.79	0.21	ns	*	*
TAA (mmol kg^{-1})[e]	4.83	5.20	4.82	6.21	4.64	6.04	5.78	6.27	1.24	ns	*	ns

[a]whole fruit including stems. Standard error ($SE_{n=6}$) was equal to 0.94 and 0.95 for OR and RC, respectively. The probability of the covering effect was estimated by comparison between the two samples.
[b] $LSD_{(0.05)}$, Least Significant Difference at a = 0.05.
[c] *Ptr*, covering treatment; *Pst*, storage time; *x*, interaction.
[d] TP, total phenolics.
[e] TAA, total antioxidant activity.
ns, not significant.
*, significant at $P < 0.05$.
**, significant at $P < 0.01$.
***, significant at $P < 0.001$.

Tab. 5: Effects of rain cover on quality attributes in 'Noire de Meched' cherries at harvest and after storage, in 2011.

	Treatment									
	Orchard (Uncovered or OR) Storage days (d)			Rain Covered Orchard (RC) Storage days (d)				Probabilities[d]		
Attribute	0	7	14	0	7	14	$LSD_{(0.05)}$[c]	*Ptr*	*Pst*	*PtrxPst*
Weight of 10 whole fruit (g)[a]	120.16	-	-	119.33	-	-	-	ns[e]	-	-
Weight of 10 seeds (g)[b]	6.73	-	-	6.71	-	-	-	ns[e]	-	-
Weight of 10 stems (g)	1.51	1.04	1.06	1.67	1.12	1.03	0.20	ns	***	ns
Weight loss of 10 whole fruit (%)[a]	-	2.11	4.43	-	1.91	4.17	0.78	ns	***	ns
*L**	31.11	30.27	29.68	31.25	31.07	30.61	1.17	ns	ns	ns
H°	14.35	14.09	13.15	15.23	16.00	15.20	2.38	*	ns	ns
C°	20.60	18.85	17.03	20.03	16.72	14.17	4.15	ns	*	ns
Firmness (N)	3.64	4.02	3.92	3.60	3.83	3.65	0.32	ns	*	ns
TSS (°Brix)	16.07	17.01	17.12	16.72	16.63	14.98	1.24	ns	ns	*
TA (g kg^{-1})	0.75	0.71	0.77	0.84	0.77	0.73	0.11	ns	ns	ns
TSS/TA	20.88	23.63	21.85	19.48	20.95	20.03	3.69	ns	ns	ns
pH	3.49	3.75	3.77	3.57	3.68	3.81	0.28	ns	*	ns
TP (g kg^{-1})[f]	0.76	0.76	0.67	0.61	0.63	0.62	0.05	***	*	*
TAA (mmol kg^{-1})[g]	5.07	4.46	5.39	4.79	4.99	4.55	0.58	ns	ns	*

[a] Whole fruit including stems. Standard error ($SE_{n=6}$) was equal to 9.18 and 11.16 for OR and RC, respectively.
[b] Standard error , $SE_{(n=9)}$ was equal to 0.10 and 0.11 for OR and RC, respectively.
[c] $LSD_{(0.05)}$, Least Significant Difference at a = 0.05.
[d] *Ptr*, covering treatment; *Pst*, storage time; *x*, interaction.
[e] probability of the covering effect was estimated by comparison between the two samples.
[f] TP, total phenolics.
[g] TAA, total antioxidant activity.
ns, not significant.
*, significant at $P < 0.05$.
**, significant at $P < 0.01$.
***, significant at $P < 0.001$.

in open orchard became important for an advanced peel development. Therefore, the effects of rain cover depend on the weather conditions, including the covering period (BORVE and MELAND, 1998).

Weight loss remains a major deteriorating factor in stored fruit. In 'Adriana', the observed loss was reduced by the covering treatment significantly on day 7 (Tab. 4). By contrast, in 'Noire de Meched' covering treatment did not exhibit any significant effect (Tab. 5). Storage time advanced fruit weight losses in both cultivars, while in 'Noire de Meched' the rate was slightly higher, by comparison, but did not exceed the level of 4.5 % at the end of the experiment. Fruit respiration and water diffusion differences in cultivars are related to different cuticular permeability to water, regulating the postharvest quality (LARA et al., 2014).

It has been observed that fruit under covers could be softer than controls (SCHMITZ-EIBERGER and BLANKE, 2012). The present results for both studied cultivars contrasted this statement. Covering of open vase cherry trees also exhibited no adverse effect on fruit quality (SOTIROPOULOS et al., 2014). Here, firmness was not influenced by covering in both cultivars, but reduced by storage days only in 'Noire de Meched'. However, all stored fruit in both cultivars retained satisfactory firmness values.

In 'Adriana', covering had no effect on TP and TAA. TAA in cherries depends mainly on TP and secondly on ascorbic acid since its contribution to TAA is much less than 15 % (WANG et al., 1996). However, the covering effects are usually unpredictable since the combined effect is more critical than each factor separately (SCHMITZ-EIBERGER and BLANKE, 2012). In this study, however, TP and TAA in 'Adriana' increased progressively after storage (Tab. 4). This significant effect of storage time, here, was not distorted after expressing the results of TP and TAA on a dry weight basis in order to eliminate the involvement of weight loss. It seemed that ripening could be continued during storage. Alternatively, the low temperature effect would be a possible explanation for the increased antioxidants in stored 'Adriana' fruit, as observed in other cases (TSANTILI et al., 2010).

In 'Noire de Meched', the advanced colour development (lower h^o) in open orchard agreed with the higher TP concentration (0.76 g GAE kg^{-1}) in comparison to covered fruit (0.61 g kg^{-1}), as shown in Tab. 5 since the red colour in cherries is mainly ascribed to anthocyanins (GONCALVES et al., 2007). The present TP results are very similar to those in USENIK et al. (2008) study determined in the same cultivar. Storage time showed a significant, but minor effect on reduced TP in uncovered fruit on day 14. TAA in this cultivar was not affected by covering or storage. Differences in the pattern of changes between TP and TAA are often observed in stored fruit and ascribed to different antioxidant activity of each phenolic compound (RICE-EVANS et al., 1996) that could increase or decrease during storage (TSANTILI et al., 2010).

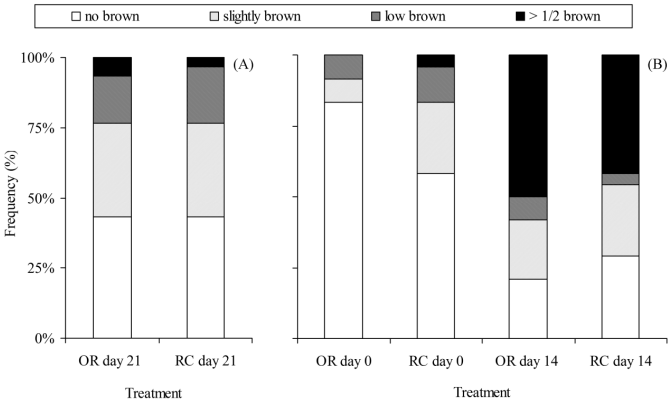

Fig. 2: Effects of rain cover on frequency of classes of stem browning (SB) in 'Adriana' and 'Noire de Meched' cherries after harvest and storage. (A), 'Adriana'; (B), 'Noire de Meched'. Each column represents 30 cherries. OR, Orchard Uncovered; RC, Rain Covered Orchard. SB classes: no brown, slightly brown (up to ¼ of stem length brownish), low brown (up to ½ of stem length brownish), brown (more than ½ of stem length brownish). Data were analyzed by c^2 tests. In A, when data were divided into three classes (no brown, slightly brown, and low brown + brown), $P > 0.05$. In B, due to small numbers in some classes, data were divided into two classes (no brown and all the rest) and showed $P < 0.001$. Partial comparisons between OR day 0 and OR day 14, and between RC day 0 and RC day 14 showed the significant storage effect ($P < 0.001$ and $P < 0.05$, respectively), while the covering effect after 14 d storage (OR day 14 and RC day 14) was not significant ($P > 0.05$).

Stem quality

Stem condition is critical for the cherry quality (LINKE et al., 2010). In particular, the green colour of stem is related to fruit freshness or to stored cherries of high quality. In the case of 'Adriana', stem browning appeared only towards the end of storage to a relatively and similarly limited extent in all fruit (Fig. 2A). In 'Noire de Meched' browning was practically observed at the end of the experiment (Fig. 2B). On day 14, in all stored fruit a percentage of approximately 25 % remained entirely green, whereas the half of the stems developed a light brownish colour covering more than the half of their length. Results showed the significance of storage on browning. Indeed, stem browning are connected to water loss and chlorophyll degradation (HARB et al., 2006). The present study measured the changes in the stem weight in 'Noire de Meched' during the experiment in 2011. The stem weight averaged 0.157 g in all fruit at harvest, was not affected by covering treatment, but significantly reduced after storage (Tab. 5). According to LINKE et al. (2010), stems showed higher water and CO_2 losses due to low resistance to vapour transfer. After harvest, there is a high rate of water loss, but water transfer occurs from the fruit body to the stem that buffers this decline initially until the situation results in decreased vapour transfer conductance, respiration and photosynthetic activity. Additionally, the chlorophyll degradation is promoted during aging, which means that browning is promoted if fruit are harvested at a later maturity state. Here, differences in stem browning between 'Noire de Meched' and 'Adriana' could be attributed to genetic or exogenous factors.

Concerning the RSR, ZHAO et al. (2013) concluded that stem retention force is not related to fruit quality and varies with genotype and year. In 'Adriana', RSR was reduced by advanced storage time, but the limited and cumulative data did not permit to distinguish any significant effect of covering or storage on it (Fig. 3A). These results resembled to those observed in other cultivar stored under similar conditions (TSANTILI et al., 2007). However, it has to be mentioned that RSR in 'Adriana' was very high, as observed subjectively. By contrast, in 'Noire de Meched', a small percentage of the stems (approximately 10 %) showed RSR values between 0 and 3 N in covered fruit after harvest, while this class did not exist in uncovered fruit (Fig. 3B). Storage, however, increased the frequency of stems with low RSR, as previously observed (TSANTILI et al., 2007).

Quantitative descriptive analysis

The three-point scale was considered appropriate for the untrained panel. The mean sensory scores obtained from the visual evaluation were 2.61, 2.51, 1.42 and 1.47 for size, peel colour, flesh colour and stem browning. The score for size was the highest among attributes, while no difference in size was observed between treated and control cherries, as also measured objectively. The panelists could distinguish the difference in peel colour between covered (2.21) and uncovered (2.71) fruit, rating higher the cherries that had developed

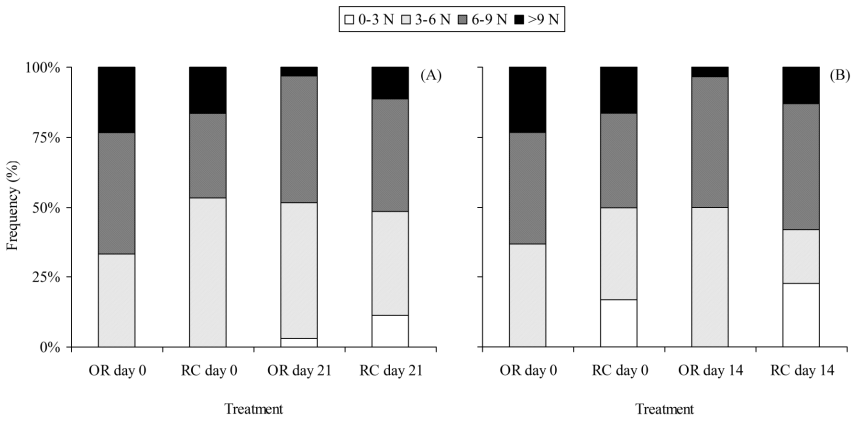

Fig. 3: Effects of rain cover on frequency of classes of resistance to stem removal (RSR) in 'Adriana' and 'Noire de Meched' cherries after harvest and storage. (A), 'Adriana'; (B), 'Noire de Meched'. Each column represents 30 cherries. OR, Orchard Uncovered; RC, Rain Covered Orchard. RSR classes: 0-3 N, 3-6 N, 6-9 N, > 9 N. Data were analyzed by c^2 tests. When data were divided into two classes, 0-6 N and > 6 N, (due to small numbers in some classes), $P > 0.05$ in both A and B. When data were divided into three classes (0-6 N, 6-9 N, > 9 N), all dual comparisons in both A and B were not significant ($P > 0.05$).

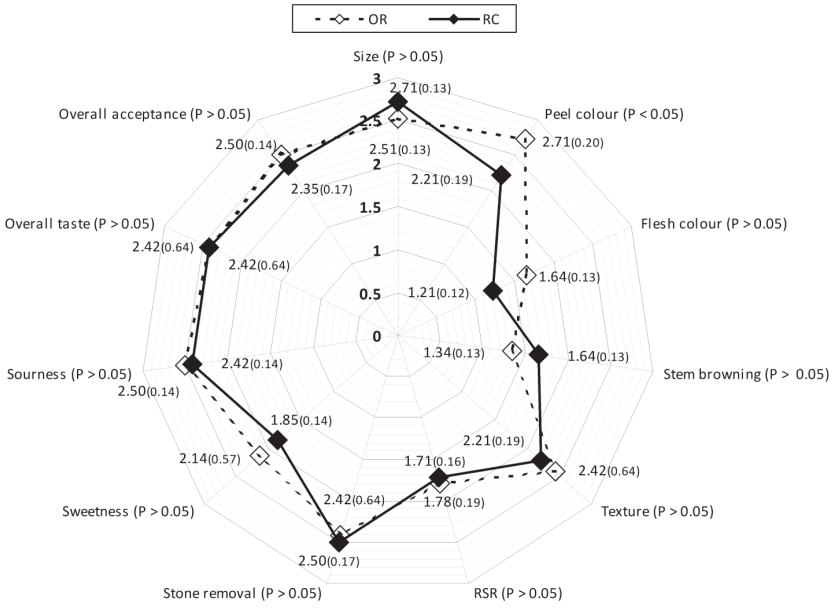

Fig. 4: Quantitative descriptive profile presented in a spider-web chart for sensory evaluation of 'Noire de Meched' cherries by 14 panelists at 20 ºC after 14 d storage at 1 ºC. OR, Orchard Uncovered; RC, Rain Covered Orchard. The evaluated attributes were: size, peel colour, flesh colour, stem browning, texture (firmness), resistance to stem removal (RSR), easiness of stone removal, sweetness, sourness, overall taste and overall acceptance. The numbers indicate the intensity of each attribute (1: low intensity; 2: medium intensity; 3: high intensity). The difference between means for each attribute was carried out by two-sample comparisons and the significance (P) is denoted within the parentheses. Each number in parenthesis next to each mean corresponds to SE.

a redder or darker red colour (Fig. 4) in agreement with the objective measurement. The difference in peel colour was the only significant attribute among the sensory ones observed. Consumers in Greece prefer dark red cherries with a sweet taste. The scores for flesh colour and sweetness were relatively low and of sourness high. Most of the attributes tested were not related to preference, at least directly. However, attributes intensities underestimated or overestimated could have been affected by the panel preference. Additionally, the panelists found that the stone was removed easily from the flesh and the RSR was moderate, while stem browning did not seem to be a serious defect. Scores for texture (firmness), overall taste and overall acceptance were 2.31, 2.42 and 2.42, respectively, indicating that the good quality of 'Noire de Meched' could be maintained at 1 ºC for 14 d.

Conclusions

'Adriana' was, indeed, an almost completely resistant to cracking cultivar at least when cultivated in Northern Greece. Due to expenses covering should not be applied to this cultivar although exhibited no adverse quality effect. The cherries were of medium weight, but had low TSS content and relatively high TA at an early harvest. 'Adriana', although a mid early ripening cultivar, retained a firm texture and attached green stems during storage at 1 ºC for time long enough to cover transport and exposure to distant markets, while the TSS/TA ratio could increase gradually, but considerably by storage time. Alternatively, the cultivar could be harvested at an advanced maturity state.

'Noire de Meched', a mid ripening cultivar, was moderately suscep-

tible to cracking, while rain cover was necessary to cope with the symptom without any adverse effect on quality. The cherries were very large (12 g), firm, with satisfactory values of TSS/TA ratio and TSS for cherry good quality. Fruit could be stored for 2 weeks, retaining their good quality attributes according to panelists and to objective determinations apart from a moderate stem browning. Panelists distinguished the redder peel colour of the uncovered fruit, being the only significant difference observed between treated and controls. Also, covering did not affect respiration rates. However, in both cultivars the Q_{10} values (0-20 ºC) of respiration showed the immediate and continuous cooling requirements of the harvested fruit.

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