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Sweet cherry research world overview 2015–2017

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Abstract: This review contains 208 citation items from 31 countries in total. The highest number of citations come from Spain (34) then from the USA (23), Italy (18) and China (16). Only one citation comes from Denmark, Georgia, Macedonia, and New Zealand. They are all included into 16 topics arranged in alphabetical order. The results or conclusions of each study are briefly described and arranged according to the year of the publication and alphabetical order of the authors. The most important topic was the physiological research containing 40 citations and then the evaluation of cultivars containing 33 citations. From the years of the review, the most important was 2017 with 122 items, whereas the least prolific year was 2015 containing only 35 items.

Keywords: *Prunus avium* L.; 16 topics; physiological research; 208 citations

Anthocyanin content. The anthocyanin content during the natural development and ripening of sweet cherries was evaluated in Spain (Teribia et al. 2016), where a strong negative correlation was found between the fruit biomass and the anthocyanin levels. The hormonal profiling revealed that the indole-3-acetic acid, GA11 and trans-zeatin levels decreased at the early stages of the fruit development, while the GA3 levels also decreased at the early stages, but later, once the anthocyanin accumulation started.

The influence of the post-harvest storage temperature of sweet cherry fruits on their colour development was studied in Greece (Tsaniklidis et al. 2017). Their results suggest that the cold storage of sweet cherries at a low, but non-chilling temperature, decelerates the accumulation of anthocyanins and consequently causes a slower colour development in the fruits.

Breeding programmes. The pollen viability of sweet cherry cultivars used in plant breeding was evaluated in Spain (Balas et al. 2017), where the cultivars '7-91-C', 'Celeste', 'Sweetheart' and 'Van' reached the highest pollen germination levels in both locations, being, therefore, suitable cultivars to use in a regional breeding programme.

The emergence of the Pacific Northwest sweet cherry breeding programme took place in the USA (Oraguzie et al. 2017). The three phases in the programme included phase one (making crosses, planting seedlings and evaluating the fruit), phase two (evaluating advanced selections on replicated trials on-farm and on-station), and phase three (evaluating elite selections for production and post-harvest attributes on grower co-operator trials prior to release). DNA information guided the breeding decisions and improved the efficiency and cost-effectiveness of the breeding operations.

Marker-assisted selection in sweet cherry breeding was applied in France (Quero-García et al. 2017). The study aimed at discovering and validating candidate genes underlying the most significant quantitative trait loci that were initiated, both by association genetics and functional genomics approaches.

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Modelling will be integrated as well in the breeding schemes in order to anticipate the consequences of the climate change and to adapt sweet cherry cultivars to the future climatic conditions.

Promising new yellow sweet cherry selections were selected in Italy (Lugli et al. 2017). In the programme, 16 new candidate genotypes propagated on two rootstocks of varying vigour under several training systems to test their growth and cropping performance were found. The preliminary trial results appeared promising for the selection of new cultivars in the future.

A sweet cherry rootstock breeding programme at the Beijing Institute of Forestry and Pomology in China was introduced (Xiaoming et al. 2017). The adaptability to salinity, alkaline soil, resistance to root tumour and leaf spot disease were tested and evaluated. More than 20 lines were selected, and three selections were proposed for release. All these selections are easily propagated and have good grafting affinity.

Bud dormancy. The chilling requirements in the 'Bing' sweet cherry cultivar were studied in Spain (Fadón et al. 2017). The results showed that, while no anatomical variations occurred along the dormancy, conspicuous cytochemical changes could be tracked along this period that may help to understand the requirement for chilling.

Controlled atmosphere storage. The impact of storing in a modified atmosphere on the eating quality and health-promoting properties of two sweet cherry cultivars was studied in Spain (Lara et al. 2015). The attributes contributing most to the acceptability were different in each cultivar. In the 'New Star' fruit, the acceptability was closely related to the perception of the cherry flavour. In contrast, the acceptability of the 'Sweetheart' fruit was mainly related to the perception of the firmness and, to a lower extent, the sweetness.

The influence of fast cold chain and modified atmosphere packaging storage on the post-harvest quality of sweet cherries was studied in Turkey (Özkaya et al. 2015), where it was found that the combination of the treatment with a fast cold chain and modified atmosphere-modified humidity packaging decreased the weight losses, fruit elasticity, pitting amount, polygalacturonase, polyphenol oxidase activities, stem visual appearance and preserved the fruit's initial quality better than the controls after the studied storage times.

The quality and physiological responses of two late-season sweet cherry cultivars 'Lapins' and 'Skeena' in a modified atmosphere packaging was studied in the USA (Wang et al. 2015), where the modified atmosphere packaging with the most appropriate gas permeability, which maintained the O_2 at 6.5–7.5 % and CO_2 at 8.0–10.0 %, slowed down the fruit senescence and maintained the quality with respect to the flavour and skin colour of the late season sweet cherry cultivars after long distance ocean shipping.

The effect of modified atmosphere packaging on the fruit quality characteristics of sweet cherry fruits was evaluated in Turkey (Aglar et al. 2017), where it was concluded that combining pre-harvest Parka treatments with post-harvest modified atmosphere packaging treatments could be used as an efficient tool in maintaining the flesh firmness of sweet cherry fruits significantly influencing the consumer preferences.

The sweet cherry is a highly perishable fruit and all the quality attributes and the level of health promoting compounds are affected by the growth conditions, picking, packing, transport, and storage according to a study in Portugal (Correia et al. 2017). Therefore, the application of a controlled atmosphere during storage was successful in delaying the quality attributes, but the lowered ascorbic acid levels.

The combined effect of antagonistic yeast and a modified atmosphere to control a *Penicillium expansum* (Link.) infection in sweet cherries was studied in Spain (De Paiva et al. 2017), where a combination of modified atmosphere packaging and antagonistic yeasts was the most effective approach to control *P. expansum* (Link.) during cold storage.

The effect of low-oxygen conditions on the radiation tolerance in *Drosophila suzukii* (Matsumura) in sweet cherries was studied in the USA (Follett et al. 2017). The Xtend PP61 bags (3.2–4.8% O_2), Xtend PP71 bags (5.4–8.6% O_2), and Xtend PP53 bags (13.6–15.4% O_2) did not enhance the survivorship to the adult stage in *D. suzukii* (Matsumura) pupae irradiated at 60 Gy in sweet cherries. The use of modified atmosphere packaging should not compromise the phytosanitary irradiation treatment against *D. suzukii* (Matsumura) in exported sweet cherries.

Evaluation of cultivars. The biochemical changes underlying the fruit firmness loss of two sweet cherry cultivars were studied in Belgium (Belge et al. 2015), where the amount of the solubilised cell wall material was closely associated to the contents of dehydroascorbic acid, suggesting the pos-

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sible involvement of oxidative mechanisms in the cell wall disassembly.

The physiological fruit properties of sweet cherry cultivars were studied in Germany (Grimm, Knoche 2015). The results of the study indicated a marked difference in the osmotic potential of the flesh and skin cells. There was little difference in the plasmolysis between the cultivars 'Hedelfinger', 'Sam', and 'Sweetheart'.

The characterisation of four sweet cherry cultivars by a physicochemical data analysis was performed in Greece (Vavoura et al. 2015), where eighteen volatile compounds were identified and semi-quantified in cherries using a solid phase microextraction in combination with gas chromatography/mass spectrometry. Carbonyl compounds were the most abundant in the sweet cherry aroma, followed by alcohols, esters and hydrocarbons/terpenes. The cherry cultivars in order of increasing amounts of volatiles were: 'Lapins', 'Canada Giant', 'Ferrovia' and 'Skeena'.

The impact of the mechanical properties of the fruit skin on the susceptibility to cracking in 'Burlat' and 'Regina' cultivar sweet cherry fruits was studied in Germany (Brüggenwirth, Knoche 2016). Their results suggest that the cell wall's physical properties account for the cultivar differences in the skin's mechanical properties and, hence, in the cracking susceptibility.

Autochthonous sweet cherry cultivars were evaluated for their fruit quality, bioactive compounds and antioxidant activity in Italy (Di Matteo et al. 2016), where the fruit profiling of eight cultivars by high resolution mass spectrometry identified a total of eight different anthocyanins and twenty-five non-anthocyanin polyphenolic compounds, mostly coumaroylquinic acid and neochlorogenic acid.

Evaluation of nine sweet cherry cultivars grafted on a Gisela 5 rootstock was undertaken in Macedonia (Gjamovski et al. 2016), where, according to the trunk cross section area, the most vigorous was 'Kordia'. On the contrary, the local cultivar 'Dolgasiska' had the lowest vigorousness. The highest cumulative yield and yield efficiency were seen in the 'Octavia' cultivar.

The phenology and yield of six sweet cherry cultivars were studied in Turkey (Sarisu et al. 2016), where, regarding the harvest time, 'Sunburst' and 'Celeste' reached harvest maturity at + 3 days, 'Lapins' at + 6 days, 'Glacier' at + 9 days, and 'Sweetheart' at + 18 days after 'Rainier' according to the average harvest time. The 'Sunburst' and 'Celeste' fruits were heavier, weighing an average of 10 g. All the cultivars had a larger fruit size than 25 mm.

The results of *S*-genotyping of 25 sweet cherry cultivars from the Czech Republic were published recently (Sharma et al. 2016), where the *S*-genotypes of 25 sweet cherry cultivars, some of which had been bred at the Research and Breeding Institute of Pomology, Holovousy, Czech Republic, were determined. The results of the study are useful for the design of crossing programmes and the orchard management of these sweet cherry cultivars.

The cultivar effect on the sweet cherry antioxidant and some chemical attributes was studied in Poland (Skrzynski et al. 2016). The research was carried out to evaluate the phenolic composition, antioxidant capacities, sugars and organic acids content of sweet cherry cultivars grown in Poland. Significant differences were observed between the tested cultivars for all the studied parameters.

The physical and chemical properties of the 'Sweetheart' sweet cherry cultivar fruits were studied in Portugal (Antunes et al. 2017). The results suggested that the fruits of the cultivar are rich in various essential elements, with the main emphasis for K and Mg, and might be considered an important dietary mineral enrichment for individuals deficient in mineral elements.

The introduction of sweet cherry cultivation in the Guadiana Lowlands region was studied in Spain (Balas et al. 2017), where the preliminary results showed some differences between the cultivars, exhibiting suitability for the commercial cultivation of some cultivars like 'Prime Giant' or '4–70'.

An 8-year study was conducted on nine sweet cherry cultivars bred at Holovousy. The cultivars were evaluated in comparison with the standard cultivars 'Burlat', 'Kordia' and 'Regina' in a modern intensive orchard using the 'Gisela 5' rootstock (Blažková et al. 2017). It was found that the 'Tamara' cultivar was unique in the total fruit quality which had the largest fruits, frequently over 12 g, and the highest fruit firmness.

The growth and reproductive behaviour of nine sweet cherry cultivars grafted onto two vegetative rootstocks was studied in Bulgaria (Radomirska, Domozetova 2017). 'Katalin' that was grafted on a 'Gisela 5' rootstock had the highest net income (519.13 lv/day), which together with other indicators determined that it was the most economically effective combination for the conditions of the experiment.

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The cultivar 'Regina' grown on three dwarf cherry rootstocks and different planting distances in the Alpe Adria Region was studied in Slovenia (Fajt et al. 2017), where the fruit weight was also influenced by the year and tree distance: the highest values were obtained at 2.5 m and the lowest at 1.5 m.

The preliminary results of the sweet cherry (*Prunus avium* L.) collection in Jumilla, Murcia was studied in Spain (García-Montiel et al. 2017), where the first cultivar to flower was 'Cristobalina' (March 3) and the last one was 'Hudson' (April 2). The interval of days between the flowering and the harvest time was different for all the cultivars and varied between 25 days for 'Primulat' and 65 days for 'Sweetheart'. 'Cristobalina' was the first to harvest and the last to harvest was 'Summerland' The lowest production was measured in 'Big Lory' with 0.6 kg/tree, the medium production was measured at 8.2 kg/tree in 'Prime Giant' and the maximum was measured in 'Sylvia' at 27.5 kg/tree. The biggest size was recorded on 'Early Lory' (30 mm) and the lowest size was recorded on 'Cristobalina' (20 mm).

The picking window of 'Sweet Aryana', 'Sweet Lorenz' and 'Sweet Gabriel' sweet cherry cultivars was studied in Italy (Grandi et al. 2017), where fruit samples were taken 7–10 days apart and variations in the weight, flesh firmness, soluble solids, acids and skin colour were analysed and the results were compared against those from fruit sampled at the usual commercial picking date.

Seven sweet cherry cultivars of Ukrainian origin were tested in Poland (Głowacka, Rozpara 2017), where 'Bajka' and 'Prestizna' were the two most promising cultivars for cultivation in central Poland, although they were less productive than 'Vanda'.

A survey to determine the most commonly used descriptors for the phenotypic characterisation and evaluation of European sweet cherry collections was published in Germany (Höfer, Giovannini 2017), where sixteen descriptors were routinely used by at least two-thirds of the respondents and deemed the most effective in describing cherry accessions, based on the answers provided by 22 sweet cherry curators.

The characterisation of cherry genotypes from North Anatolia was presented by a contribution from Turkey (Köse et al. 2017), where promising cherry genotypes were determined, using a "Modified Weighted-Ranked Method" based on the fruit weight, yield, and appearance of the fruit, flavour, harvest date and soluble solids content; six cherry genotypes were determined as being promising. The genotype 'A5' of the promising cherry genotypes had the highest score, followed by 'A6', 'A4', 'A12', 'A8' and 'Ş2'.

The content of bioactive and volatile compounds in sweet cherry cultivars was evaluated in Spain (Legua et al. 2017). The cultivars with the highest antioxidant activity were 'Burlat' and 'Brooks'; very important from a health point of view. Regarding the volatile compounds, thirty-one volatile compounds were isolated with 'Van' having the highest contents. The '57', and 'Burlat' sweet cherry genotypes were the most interesting with respect to the "health benefits".

The suitability of sweet cherry cultivars for the Pacific Northwest of the United States was surveyed (Long et al. 2017), where consumer trait preferences are the first step in releasing new cultivars that encourage repeat buying. The traits desired by growers must also be taken into consideration. New cultivars must produce a large, firm fruit that resists rain-cracking and arrives well in distant markets after several weeks under shipment.

Two local sweet cherry cultivars were selected in Belgium (Magein 2017). The growth, bloom and fruit characteristics as well as the S-allele compatibility, fruit cracking, and *Monilia* and *Cylindrosporiosis* susceptibility of these cultivars are presented in the study.

The profile of the phenolic compounds and antioxidant properties of six sweet cherry cultivars were studied in Italy (Martini et al. 2017). Upon obtaining their results, it was stated that the anthocyanins and flavour patterns have the potential to be used for the determination of a varietal assignment of cherries.

The biological and agricultural properties of sweet cherry (*P. avium* L.) cultivars were studied in Georgia (Maglakelidze et al. 2017), where the cultivars 'Samba', 'Burlat' and 'Giorgia' contain the biggest contents of soluble dry substance at 13.6%, 13.8% and 14.6%, respectively. The contents of the total sugars in the cultivars vary from 9.4% ('Samba') to 6.8% ('Moro'). The acidity of the cultivars is, on an average, 0.42%. The three cultivars with the best biological and commercial properties were 'Burlat', 'Samba' and 'Giorgia'.

The effect of the inoculum concentration and leaf age on bacteria canker disease development in sweet cherry cultivars in the USA were studied (Mgbechi-Ezeri et al. 2017), where the mean score in the detached leaf assay was significantly greater than the attached leaf assay. The data provide a foundation for screening a wider sweet cherry germplasm for resistance or susceptibility to bacterial canker.

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The effect of the temperature on the pollen germination of sweet cherry cultivars grown *in vitro* was studied in Serbia (Milatović, Nikolić 2017). The obtained results indicate a differential cultivar response to the temperature during the pollination period. The better adaptation of some cultivars to low temperatures during the flowering could be an indicator of their wider geographical adaptation.

The evaluation of genetic resources of the sweet cherry for the selection of breeding materials was undertaken in Korea (Nam et al. 2017), where ten breeding materials containing useful traits for the development of new cultivars were selected.

The results from a comparison of old cherry cultivars grown in the Czech Republic upon their chemical composition and bioactive compounds were published in Poland (Nawirska-Olszańska et al. 2017), where the 'Lyonská raná' cultivar was characterised by the highest sweetness, also having a high polyphenolic content and high antioxidant capacity, while having the lowest content of organic acids at the same time. The 'Šakvická' cultivar was characterised by the highest sugar and acid contents with low concentrations of anthocyanins and phenolics while having a low antioxidant capacity.

The chilling requirements of sweet cherry cultivars were evaluated in Italy (Palasciano, Gaeta 2017), where the chilling portions of the evaluated cultivars ranged from 58 to 84 days.

The agromorphological characterisation of traditional sweet cherry cultivars was studied in Spain (Pérez-Sánchez et al. 2017), where some of the studied cultivars showed distinctive and interesting agronomical characteristics, such as low susceptibility to fruit cracking and high levels of soluble solids and total polyphenols. This was the case with the late cultivar widely distributed through the Alagón river valley called 'Moracha'. Its fruits were quite sweet (19.85 °Brix), resistant to cracking (3%) and rich in polyphenols (1.69 g of gallic acid 100 g/dry weight).

A sweet cherry fruiting wall as a training system was evaluated compared to a single axis and vase using the cultivar 'Folfer(cov)' in France (Pinczon du Sel et al. 2017), where the fruiting wall had entered production later, and with lower yields than all the other training system/rootstock combinations in this trial.

The choice of pollenisers for the 'Kordia' and 'Regina' sweet cherry cultivars was studied in Chile (Sagredo et al. 2017), where 'Sunburst' was a good polleniser for 'Kordia'; and 'Schneider', 'Summit' and 'Katalin' were good pollenisers for 'Regina'. The effective pollination period was about 5 to 6 days for 'Regina' and 'Kordia', highly influenced by the temperature.

The predictive model for the 'Lapins' sweet cherry dry matter content using a visible/near-infrared spectrometer was developed in Canada (Toivonene, Hampson 2017). The results indicated that the dry matter in the sweet cherry cultivar 'Lapins' can be predicted accurately and non-destructively using visible/near-infrared spectroscopy.

Sweet cherry cultivars were tested in Belgium (Vercammen, Gomand 2017), where, with the exception of 'Skeena', these cultivars all ripen in the 3rd to 6th week of the harvest season. Thus, there is still a need for cultivars that ripen very early or very late. Other interesting cultivars in the first screening are 'Vanda', 'Poisdel', 'Rubin' and 'Penny'.

Fruit cracking. The impact of the pre-harvest application of a seaweed based biostimulant on sweet cherry cracking was studied in Portugal (Correia et al. 2015). The results showed that the application of the biostimulant reduced the production losses caused by cracking without compromising either the quality or the yield in the studied cultivars.

An assessment of the susceptibility and prevention of cracking of the cultivar 'Skeena' was evaluated in the USA (Hoppe et al. 2015), where the different cracking expression between the sites was related to the precipitation levels, irrigation and fruit growth rates. A significant decrease in the post-harvest fruit pitting was observed for the fruits treated by gibberellic acid.

Mechanisms of the sweet cherry fruit cracking was studied in Bulgaria (Koumanov 2015), where it was stated that expensive rain-preventing covers may be replaced by cheaper systems for cooling overhead (micro)sprinte, which should be operated on the days with an unfavourable forecast.

The association between the concentration of n-alkanes and the tolerance to cracking in commercial varieties of sweet cherry fruits was studied in Chile (Rios et al. 2015). Fruit cracking is one of the major economic losses in cherry production worldwide. The factors involved in the differential tolerance among varieties are unknown.

Spray applications to prevent rain-induced sweet cherry cracking were studied in the USA (Kafle et al. 2016). The findings of the study could serve as a basis for determining suitable Ca-based chemical re-application rates and concentrations on sweet cherries to minimise the fruit cracking without affecting the produce quality.

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The effectiveness of potential products to reduce the rain cracking of cherry fruits was studied in the Czech Republic (Suran et al. 2016), where no differences were recorded between the tested products on the cultivars with a lower flesh firmness ('Sweet Early', 'Burlat').

The physiological aspects of rain cracking in sweet cherries were studied in Germany (Winkler et al. 2016). The results established that the flow of xylem is likely drawn into the fruit from the tree by the apoplastic tension in the fruit, resulting from the osmotic water uptake from the apoplast to the symplast and from transpiration.

Whether rain cracking in sweet cherries is due to the excess water uptake and skin phenomena was studied in Germany (Winkler et al. 2016). The results indicate that rain cracking in sweet cherries is a localised phenomenon which is not related to the net fruit water balance (the critical turgor hypothesis), but is the result of the more local exposure of the fruit skin to liquid-phase water (the zipper hypothesis).

The effectiveness of new rain-protection systems on the cracking, ripening date and fruit quality of sweet cherry cultivars was evaluated in Italy (Grandi et al. 2017). The results of the study showed that the models were capable of assuring good commercial yields even in seasons of heavy rainfall when unprotected orchards are at risk of losing their entire crop.

Water transport through the sweet cherry fruit surface in relation to rain cracking was studied in Australia (Knoche, Measham 2017). Analysing the water transport on this basis allowed one to predict the effect of selected fruit factors on the net water transport; the leakiness of the pedicel/fruit juncture, the effect of the fruit size, the magnitude of the driving force, the skin permeability or the effect of environmental variables, such as the relative humidity or the percentage of the fruit's wet surface area.

Rain-induced cracking of sweet cherries was studied in Germany (Knoche, Winkler 2017). This study focused on the mechanistic processes potentially associated with the rain-induced cracking of sweet cherry fruits, such as the fruit-water relationships, fruit and tissue water potentials and their components and the development of the fruit skin.

High tunnel production systems of sweet cherries, as the best protection against fruit cracking, were evaluated in Norway (Meland et al. 2017). In these tunnels, feathered 1-year-old sweet cherry 'Sweetheart'/'Colt' trees were planted in two rows at a spacing of 2 × 4 m in each tunnel. The temperatures inside the tunnels were 0.3 °C higher on average during the entire season, but exceeded 30 °C on the same two hot days.

The time of the tree pruning in relation to the fruit cracking was studied in Australia (Measham et al. 2017), where pruning during rainfall in the three weeks prior to harvest maturity reduced the fruit cracking, while pruning prior to the rainfall in the same period did not impact the cracking.

The impacts of a calcium application on the sweet cherry cultivar 'Van' in relation to fruit cracking were studied in Australia (Measham et al. 2017), where enhanced Ca uptake rates were recorded in the sweet cherry with the use of thickeners and surfactants. A major limitation of using direct Ca applications to prevent cracking is the unsightly residue left on the fruit; therefore, the benefits must outweigh this disadvantage.

Fruit quality. The chemical characterisation and bioactive properties of sweet cherry fruits were studied in Portugal (Bastos et al. 2016). This study reports innovative results regarding the chemical and bioactive properties of sweet cherry stems and confirmed the nutritional and antioxidant characteristics of their fruits.

The effects of pre-harvest benzyladenine and gibberellin treatments on the post-harvest fruit quality of a sweet cherry were studied in Turkey (Canli et al. 2015), where the fruits treated with an optimum dose of benzyladenin and gibberellin were larger and firmer than the untreated fruits at harvest.

The relationship between the sweet cherry fruit quality attributes and wholesale prices as well as the modernisation of orchards was studied in Poland (Florkowski, Lysiak 2015). Upon obtaining their results, it was stated that the sweet cherry production declines in the region of Poland with the introduction of modern production technologies, while the increasing yields and produced volume also creates opportunities for increased exports to countries outside the EU.

Freshness maintenance due to bio-based packaging of sweet cherries was the object of study in the USA (Koutsimanis et al. 2015), where the new package matched the consumer demand for high-quality fresh fruit ready for consumption in convenient bio-based packaging and the extended fruit marketability and consumer satisfaction desired by industry.

The impact of flower thinning on the fruit quality was evaluated in Serbia (Milić et al. 2015), where a Silwet surfactant applied at the rates of 1 or 3 ml/L

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was found to consistently thin self-fertile sweet cherry cultivars, leading to better fruit quality.

The effect of the fruit size on the fruit characteristics in the sweet cherry cultivar 'Kordia' was studied in Slovenia (Usenik et al. 2015), where larger fruits were more coloured, with better pomological traits which changed the composition of nutritive compounds and phenolics.

Antioxidant systems in sweet cherry fruits at harvest and during storage in relation to the fruit quality were studied in Spain (Valverde et al. 2015), where pre-harvest treatments with 1 mM MeSA at three key dates of sweet cherry growth and ripening improved the fruit quality attributes at the time of harvest and after the post-harvest storage, showing that MeSA could be a safe and environmentally friendly tool with potential practical applications to improve the sweet cherry fruit quality.

The aim of the study from Germany (Brüggenwirth et al. 2016) was to quantify the xylem, phloem, and transpiration contributions to the overall water balance of developing the sweet cherry fruit. Fruit volume changes with time were inferred from the measured diameter changes. The pedicel xylem and phloem sap-flow rates, and fruit transpiration rates were inferred from the fruit volume changes.

The fruit quality changes of six different cherry varieties in low-temperature refrigeration were studied in China (Maosi et al. 2016). The results showed that a dynamic monitoring and quality assessment system could monitor the changes of critical micro-environmental parameters during the express logistics, and the freshness prediction model showed high accuracy (the relative error was controlled within 10%).

The impact of pre-harvest gibberellic acid treatments on the bioactive compounds and fruit quality of sweet cherry cultivars was studied in Turkey (Ozkan et al. 2016), where it was observed that the gibberellic acid treatments retarded the red colour development in all three cultivars.

The composition of sweet cherry fruits was studied in Spain (Serradilla et al. 2016), where a variety of phytochemicals (e.g., phenolics, anthocyanins, and flavonoids) contributing to the functional properties of sweet cherries was characterised and discussed in the paper.

The effect of phytosanitary irradiation and methyl bromide fumigation on the sensory quality of sweet cherry fruits was studied in the USA (Thang et al. 2016), where the irradiation caused an immediate decrease in the firmness of the fruits without any further significant changes during storage. The methyl bromide fumigated fruits exhibited greater damage and mould growth than the control and irradiated samples during storage.

The impact of an oxalic acid application on the sweet cherry properties at three physiological stages (at pit hardening, initiation of colour changes and initiation of maturity) was studied in Spain (Zapata et al. 2016), where the pre-harvest treatment with oxalic acid was able to increase the fruit quality and production of both the 'Sweetheart' and 'Sweet Late' cultivars.

The attributes which consumers look for in sweet cherries were studied in the USA (Zheng et al. 2016), where a mixed logit model and a latent-class logit model were used to estimate the consumer willingness to pay for the attributes and helped to identify groups of consumers based on those preferences. It was found that consumers of sweet cherries will pay the greatest premium for the sweetness and the smallest premium for the fruit size.

The objective of the study from Chile (Ardiles, Ayala 2017) was to compare the effect of applications of Erger® and hydrogen cyanamide (HC) is used to overcome insufficient winter chilling in sweet cherry (*Prunus avium* L.). The fruit set was similar among the treatments.The budbreak promoters significantly increased the fruit weight, however, Erger® + $Ca(NO_3)_2$ not only increased the fruit size, but it also shifted the distribution curve to the larger sizes.

The possibilities of achieving high fruit quality in sweet cherries were studied in Australia (Bound et al. 2017), where the earliest fruit thinning treatments were the most effective.

In Canada, research was undertaken to evaluate the effects of a cherry cuticle supplement on the sensory, physicochemical, and visual characteristics of the 'Skeena' sweet cherry (Cliff et al. 2017), where fruit treated with the cherry cuticle supplement had lower instrumental fitness compared with the control, which was most pronounced after 28 days.

The impact of guar gum and a ginseng extract on the fruit quality of the sweet cherry was studied in China (Dong, Wang 2017), where the shelf life of sweet cherry fruits was extended for about 8 days, demonstrating, for the first time, that the combination of guar gum and a ginseng extract as edible coating materials has great potential in expanding the shelf life of fruits.

The impact of soluble solids and the dry matter content on the sensory quality in sweet cher-

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ries was studied in the USA (Escribano et al. 2017), where the consumer preference was connected with a high dry matter content and soluble solids content between 0.687 to 0.911%.

The influence of calcium and gibberellic acid pre-harvest treatments on the fruit quality and sensory parameters in sweet cherries was studied in Spain (González-Gómez et al. 2017), where, the effect of different treatments on the fruit sensory attributes and quality parameters (fruit firmness, acidity, soluble solid content and antioxidant activity) was significant.

The impact of postponed picking of new cherry cultivars on the fruit quality was studied in Italy (Grandi et al. 2017). The results showed that the quality properties of the late-picked fruit improved, especially in terms of the weight and soluble solids, and that the flesh firmness remained above the minimum market threshold values.

The effect of post-harvest display conditions on the sweet cherry stem quality was studied in the United Kingdom (Golding et al. 2017). The overall 'freshness' of the stems was significantly affected by all the storage factors and is a better indication of stem acceptability. The results clearly demonstrated the importance of the temperature and relative humidity during the retail display of cherries.

The effect of in-field hydrocooling on the post-harvest quality of sweet cherries was studied in Spain (Muñoz et al. 2017). The results showed that the new cooling strategy would likely have a big impact on the customer acceptance. Compared to sweet cherries cooled 24 hours after harvesting, those pre-cooked in the field showed a higher acceptability index (total soluble solid/total acidity), and improved appearance, due to their greener and more turgid pedicels, and their minor visual dehydration.

A new technology of sweet cherry growing was developed in Germany (Overbeck et al. 2017). There covering the cherry trees in spring to force flowering and enhance the ripening can improve the synthesis of bioactive compounds and provide the consumer with an early high-quality fruit. (Overbeck et al. 2017).

The role of nitrogen fertigation on the sweet cherry fruit quality and the consumer perception of quality at harvest and post-harvest was studied in Australia (Swarts et al. 2017). The results demonstrated an immediate effect of increased nitrogen supply on the cherry nitrogen concentration and fruit firmness.

The maintenance of sweet cherry quality attributes as affected by innovative post-harvest treatments was evaluated in Spain (Valero 2017). In the study, the current knowledge about some innovative post-harvest treatments with the aim to reduce the post-harvest quality losses was shown.

The effects of the harvest maturity and crop load level on the fruit quality of the 'Lapins' and 'Sweetheart' sweet cherry cultivars were studied in Canada (Wang, Einhorn 2017). The results indicated that the crop load level was positively related to the yield, but inversely related to the fruit quality. The appropriate harvest timing and proper management of the crop load can markedly improve the fruit quality, resistance to pitting, and storage/shipping quality of the 'Lapins' and 'Sweetheart' sweet cherries.

The effects of optimising the pre-harvest application rate of gibberellic acid (GA_3) and homobrassinolide (HBR) to improve the shipping quality of sweet cherries were studied in Canada (Wang, Einhorn 2017). The results indicated that GA_3 delayed the harvest timing (slowed the colour development), but the harvest delay did not correspond to improvements in the fruit size for the studied cultivars. HBR at 1 ppm increased the fruit firmness of 'Sweetheart', but did not affect the fruit colour, fruit size, soluble solids content, titratable acidity, pitting susceptibility, skin darkening of both 'Sweetheart' and 'Skeena' at harvest or following four weeks of storage at 0 °C.

The present state of sweet cherry consumer requirements for fruit quality was studied in South Korea (Yoon et al. 2017). The study demonstrated different that shapes of sweet cherry trees for their effects on cherry production.

The effects of a gibberellic acid application on the sweet cherry cultivars properties were studied in Chile (Zoffoli et al. 2017). The fruit size was improved and the fruit tissue was less sensitive to compression and impact damage following the gibberellic acid treatment. 'Sweetheart' was more sensitive to impact and compression damage and had lower values of the rheological parameters than 'Bing'.

Genetic research. A genetic study focused on the fruit firmness and weight control in sweet cherry took place in Italy (Campoy et al. 2015), where the traits were studied using two F1 sweet cherry progenies derived from modern cultivars. A quantitative trait locus analysis allowed the identification of the genomic regions.

The mapping of candidate genes involved in the bud dormancy and flowering time in sweet cherry was undertaken in France (Castède et al. 2015),

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where 25 candidate genes were genetically mapped in at least one of the two studied progenies, and all were *in silico* mapped. The co-localisation between the candidate genes and the quantitative trait loci (QTLs) associated with the temperature requirements and flowering date were identified for the first time in sweet cherries.

The construction of high-density sweet cherry linkage maps using microsatellite markers detected by genotyping-by-sequencing was undertaken in Chile (Guajardo et al. 2015). These new high-density linkage maps provide valuable information on the sweet cherry genome, and serve as the basis for the identification of quantitative trait loci and genes relevant for the breeding of the species. Linkage maps are valuable tools in genetic and genomic studies.

Linkage maps for the sweet cherry were constructed in China (Wang et al. 2015), where a high-density 'W × L' genetic linkage map has the potential to enable the high-resolution identification of quantitative trait loci agronomically-relevant traits and accelerate sweet cherry breeding.

A comparative transcriptome analysis of genes involved in the anthocyanin biosynthesis in the red and yellow fruits of sweet cherry was performed in China (Wei et al. 2015). The results provided a platform for further functional genomic research on this fruit crop and a reference for studying complicated metabolic processes in non-model perennial species.

The transcriptional regulation of specific genes during sweet cherry fruit development in response to abscisic acid and auxin at the onset of fruit ripening was studied in China (Wang et al. 2015), where an exogenous abscisic acid treatment at 28 days after full bloom decreased the indole acetic acid level and promoted fruit ripening by increasing the anthocyanin and soluble solids content.

The genetic diversity, linkage disequilibrium, population structure and construction of a core collection of *P. avium* L. landraces and bred cultivars were studied in France (Campoy et al. 2016). The study constituted the first population genetics analysis in a cultivated sweet cherry using a medium-density single nucleotide polymorphism (SNP) marker array.

The use of DNA test prediction of the sweet cherry fruit colour in breeding was studied in the USA (Sandefur et al. 2016), where one assay, subsequently named Pav-Rf-SSR, was used to screen 221 pheno-typed individuals of the RosBREED sweet cherry reference germplasm set and accurately differentiated individuals with mahogany and blush. Pav-Rf-SSR can be used in DNA-informed breeding schemes to efficiently and accurately predict the genetic potential for the fruit colour and was one of the first DNA tests publicly available to test sweet cherry fruit quality traits.

A quantitative trait locus analysis and candidate gene mapping for the skin and flesh colour in sweet cherry fruit was performed in China (Sooriyapathirana et al. 2016), where segregations for the colour measurements (card, L^*, a^*, and b^*) did not fit normal distributions; instead, the distributions were skewed towards the colour of the dark-fruited parent. A major quantitative trait locus for the skin and flesh colour was identified on linkage group (LG) 3.

The results from a study in Chile (Yarur et al. 2016) suggest that the flowering time gene is expressed in the leaves and buds and is involved in the floral meristem determination and bud development in the sweet cherry. The protein travels through the phloem to the shoot apical meristem, where it induces the flower determination.

The genetic basis of the sweet cherry floral morphology was studied in Japan (Beppu et al. 2017), where the MADS-box genes 'PaAG' and 'PaSHP' were homologous to class C floral identity genes.

The genetic structure of a quantitative trait locus hotspot on chromosome 2 in the sweet cherry was studied in the USA (Cai et al. 2017), where a genomic region of particular interest for sweet cherry breeding and a quantitative trait locus "hotspot" on chromosome 2 quantitative trait locus for the fruit size, firmness, sweetness, and flowering time were reported to map to this region.

The allelic status of the PavCNR12 gene in Ukrainian sweet cherry cultivars was studied (Ivanovych, Volkov 2017), where a new convenient method for the identification of the allelic variants of the PavCNR12 gene using CAPS-markers was proposed. A significant prevalence of the desirable allele PavCNR12-1 over the alleles PavCNR12-2 and -3 was found among the studied cultivars.

A paternity analysis in the sweet cherry cultivar 'Rainier' open pollination population using S-alleles and microsatellite genotyping was performed in Chile (Guajardo et al. 2017). In this population, the parents exhibited contrasting phenotypes for the skin and flesh colour and berry firmness, among other agronomically important traits, making this population very interesting for future genetic studies.

The genome sequence of the sweet cherry for use in genomics-assisted breeding was studied in Japan

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(Shirasawa et al. 2017), where the sequences covered 77.8% of the 352.9 Mb sweet cherry genome, as estimated by the k-mer analysis, and included > 96.0% of the core eukaryotic genes. A high-density consensus map with 2.382 loci was constructed using double-digest restriction site-associated DNA sequencing.

A genetic linkage map of the sweet cherry concerning the S-locus was studied in the USA (Iezzoni 2017), where 1 825 polymorphic simple sequence repeats in total were verified in the sweet cherry and 2 085 polymorphic simple sequence repeats, for which the dosage could be resolved, were verified for the sour cherry. In a separate project, a total of 335 genomic regions polymorphic in two sweet cherry cultivars were identified with simple sequence repeat markers.

In a study undertaken in Japan (Shirasawa et al. 2017), the genome sequence of the sweet cherry using a next-generation sequencing technology was determined. The total length of the assembled sequences was 272.4 Mb, consisting of 10, 148 scaffold sequences with an N50 length of 219.6 kb. The sequences covered 77.8% of the 352.9 Mb sweet cherry genome, as estimated by the k-mer analysis, and included > 96.0% of the core eukaryotic genes. It predicted 43.349% of complete and partial protein-encoding genes.

Harvest time. A model system for the off-season sweet cherry production was developed in China (Zhang et al. 2016). The early sweet cherry production in northern China has the potential to generate high economic returns for producers, strengthen the local economy and to meet the consumer demand.

The maturation and picking time for sweet cherries was studied in Denmark (Kaack 2017), where the berry weight and the level of anthocyanin significantly increased according to the positive multiplicative equations, while the stone percentage and cyanide content decreased according to the negative multiplicative equations during the picking period.

An innovative non-destructive device for cherry fruit ripening and quality assessment was developed in Italy (Nagpala et al. 2017). A new spectroscopy portable device based on visible and near infrared spectroscopy developed by Bologna University was used to follow the ripening evolution of sweet cherry fruits.

Health impact. The impact of sweet cherry consumption on human health was studied in Portugal (Matias et al. 2016), where the antioxidant phenolic-rich extract displayed effective intracellular radical scavenging properties in the intestinal epithelial and neuronal cells challenged with oxidative stress, but showed a different order of effectiveness regarding the modulation of the endogenous antioxidant system.

The health benefits of the sweet cherry were reviewed in Portugal (Gonçalves et al. 2017). The findings of the review supported the evidence that sweet cherries can be applied in pharmaceutical and food formulations, since they are able to diminish the free radical species and proinflammatory markers, preventing and/or ameliorating oxidative-stress disorders.

The impact of sweet cherry consumption on human health was studied in the USA (Kent et al. 2017), where it was stated that inclusion of an anthocyanin-rich beverage may be a practical and feasible way to improve the total anthocyanin consumption in older adults with mild-to-moderate dementia, with the potential to improve specific cognitive outcomes.

The bioprotective capacity of sweet cherry fruits was studied in New Zealand (Leong et al. 2017). The 'Sweetheart' and 'Stella' cultivars demonstrated the greatest bioprotective capacity, suggesting that the anthocyanin levels are better markers of a cultivar's ability to protect human cells from oxidative stress than vitamin C.

Irrigation impact. The interaction of irrigation and soil management on the productivity and fruit quality of sweet cherries was studied in Canada (Neilsen et al. 2015), where the overall cool, wet spring weather strongly affected the annual yield and fruit quality, often overriding the cultivar and soil and water management effects. The soil moisture content during the growing season was often higher in the soils that received high-frequency irrigation compared with the low-frequency irrigation.

The response of a long-living cherry cultivar to contrasting irrigation strategies was studied in Spain (Nieto et al. 2017), where the regime using the average farmer's irrigation water and only habitual post-harvest irrigation practices maintained a good yield similar to that obtained by other regimes, which used pre-harvest irrigation, getting a reduction in the consumption of water up to 60%.

The effect of irrigation on the post-harvest quality of two sweet cherry cultivars was studied in Spain (Velardo-Micharetet et al. 2017), where the fruits of cherries grown under irrigation in both studied cultivars had a higher rot incidence.

Orchard protection. The pesticides used in sweet cherry orchards were analysed in Turkey

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(Yilmaz 2015). The chi square test analysis showed that there was a significant relationship between the dosages of the pesticides used by farmers and the farm size, listening to an agriculture related programme on radio, the information needed in disease, insect and pest management, applying protective pesticides and use personal protection equipment.

The results of research focused on the protection of a sweet cherry orchard to pre-harvest rot were published in Australia (Barry et al. 2016), where the spore abundance was found to occur throughout the sweet cherry season from flowering and a new molecular method was developed to quantify spores of *B. cinerea, M. laxa* and *M. fructicola*.

The control of post-harvest fungal rot on sweet cherries using a pomegranate peel extract was studied in Italy (Nicosia et al. 2016). The pomegranate peel extract treatment showed a residual effect as it was effective in inhibiting infections occurring at 6, 12, and 24 hours after the application of the extract in the fruit wounds.

The integrated control of fungal rot of sweet cherry was performed in the UK (Berrie et al. 2017). Trials were conducted to evaluate measures to eliminate or suppress overwintering inoculum on mummified fruit. The physical removal of mummified fruit from the trees was most effective.

Nets and covers to protect cherry trees from rain and insects were studied in France (Charlot, Weydert 2017). The efficacy of a fully-protected orchard by using nets and covers as well as row-by-row protection was tested for two years.

A review on the sweet cherry in Turkey characterised this leading worldwide cherry producer and exporter (Demirsoy et al. 2017). High-density modern orchards were established using new cultivars, rootstocks, training systems and growing techniques. It seems that Turkey is changing from conventional to modern cherry production and will continue to be a leader in cherry production in the world.

The development of sweet cherry production in the Cova da Beira region in Portugal was presented (Dias et al. 2017), where it was stated that the organisation and concentration of the production, the certification of the product and the information/marketing at the consumer level are critical to the further development of the sweet cherry production in the region.

Launching a sweet cherry crop in the Murcia region in Spain was presented (Frutos, Ureña 2017), where it was stated that the thanks to seven years of work of the Cherry Working Group, it was possible to introduce a sweet cherry culture as a new crop in Murcia. Year after year, the sweet cherry surface planted in Murcia has increased.

The potential for intensive sweet cherry production was studied in Bulgaria (Koumanov, Tsareva 2017), where it was concluded that modern equipment, high and multivalent grower qualifications and the strict execution of each operation are imperative. Micro-irrigation and fertigation are indispensable elements of any intensive sweet cherry production.

Orchard protection against bacterial canker in high-density sweet cherry orchards was studied in the USA (Lillrose et al. 2017). Research was conducted to examine whether a prophylactic application over a range of potential control treatments, including antibiotics plant defence inducers, or microbial bio-controls, can reduce flower infections.

The characterisation of sweet cherry high tunnel production systems was published in Norway (Meland et al. 2017). The harvest period was the second half of August. The average yield in tree-1 was 8.8 kg (11 t/ha) in the fourth leaf and 18.8 kg (23.5 t/ha) in the fifth leaf. The fruit size measurements found that 80% of the fruits were larger than 30 mm in diameter in the fourth leaf and 51% of the fruits were larger than 30 mm in the fifth leaf. The total soluble solid content was generally high (17–18%).

A trial using a semi-automatic, multi-span, plastic greenhouse with double heat sources for growing sweet cherries took place in China (Zhang et al.2017), where, over the two years of the trial, the sweet cherry yields in this new system were increased by 9.5% and the percentage of high-quality sweet cherry was increased by 80% compared to a traditional plastic greenhouse.

The detection of *Prunus* necrotic ringspot virus and Prune dwarf virus in sweet cherries was studied in China (Zong et al. 2017). Twenty-two of the samples were infected by both viruses simultaneously and caused more serious symptoms, including plant structural dwarfing, shortened internodes and fruit blast.

Physiological research. The effects of ethanol and acetic acid fermentation on the total antioxidant activities and phenolic substances of sweet cherry juice were studied in Turkey (Budak 2015). An investigation into the total solids, pH, soluble solids, phenolic substances, Oxygen Radical Absorbance Capacity (ORAC) and Trolox equivalent antioxidant capacity (TEAC) of cherry juices, mac-

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erated cherries wine, and vinegars was analysed and described.

The bioassay-based isolation and identification of phenolics from the sweet cherry was studied in China (Cao et al. 2015). Three fractions promoted the HepG2 glucose consumption to different levels, with the promotion effects of the hydrocinnamic acid-rich fraction (HRF) and flavonol-rich fraction (FRF) stronger than that of the anthocyanin-rich fraction (ARF). The results provide guidance on the use of the sweet cherry as a functional fruit.

Temporal post-harvest changes on the qualitative attributes and phytochemical parole of sweet cherry fruits were studied in Greece (Goulas et al. 2015). The fruit antioxidant capacity was enhanced with the progress of the shelf-life period, concomitant with the increased levels of total anthocyanin and of phenolic compounds. The 'Ferrovia' fruit presented higher contents of neochlorogenic acid and p-coumaroylquinic acid throughout the shelf-life period.

The physicochemical characteristics, antioxidant activity, organic acid and sugar contents were studied in Turkey (Hayaloglu, Demir 2015), where darker cultivars exhibited higher antioxidant activities than lighter ones. The 'Bing 'and 'Sweet Heart 'cultivars contained higher levels of malic acid, which was the most intense organic acid in the sweet cherries.

Optimisation of the light interception in an intensive sweet cherry orchard was studied in Hungary (Steiner et al. 2015). The total leaf area of the trees and the leaf area index was considerably influenced by the cultivar and rootstocks. The canopy cover rate of the orchard area increased from 0.4–0.5 to 0.6–0.7 with decreasing spacing.

The sweet cherry research review from Australia (Chockchaisawasdee et al. 2016) was focused on the post-harvest preservation, processing and trends for its future use. In the review, the main physicochemical properties of sweet cherries, as well as the bioactive components and their determination methods were described. The study emphasised the recent progress of post-harvest technology, such as controlled/modified atmosphere storage, edible coatings, irradiation, and biological control agents, to maintain sweet cherries for the fresh market.

A metabolic profile comparison of fruit juice from two sweet cherry cultivars was studied in Italy (Girelli et al. 2016). Despite the usually lower commercial value of the 'Ferrovia' and 'Giorgia' cultivars, they showed a higher content of malic acid and phenolic compounds which have important well-known nutraceutical properties such as antioxidant activity and metabolism stimulation characteristics of twelve sweet cherry cultivars grown in Turkey were observed (Hayaloglu, Demir 2016). It was concluded that the same compounds for phenolic or volatile profiles of sweet cherries were similar in the qualitative aspects; however, quantitative differences were observed in these cultivars.

The contents of the physico-chemical traits, bioactive compounds and the antioxidant capacity in 25 sweet cherry autochthonous cultivars were evaluated in Italy (Matteo et al. 2016). Upon the results of this study, the cultivars 'Mulegnana', 'Nera' and 'Pagliarella' were better performing for fruit quality traits which shared a high fruit level in the phenolics, flavonoids and antioxidant capacity.

The spring frost vulnerability of sweet cherries under controlled conditions was studied in Germany (Matzneller et al. 2016), where four empirical functions were developed which allow one to calculate the possible frost damages on sweet cherry buds or flowers at the investigated development stages.

The application efficacy using common plant growth regulators in sweet cherry trees was studied in the USA (Niemann et al. 2016). The fruit treated by a solid set canopy delivery system were heavier (+ 5%) than the untreated control.

The susceptibility of sweet cherries to mechanical damage of the fruits was studied in Chile (Param, Zoffoli 2016). The structure of the flesh tissue in the harvest-ripe fruits was measured using textural analysing equipment and was further described by light microscopy.

Cultivar-dependent traits of sweet cherry polyphenols were studied in Italy (Picariello et al. 2016), where it was found that the anthocyanin profile is cultivar specific. Thus, after the opportune validation over a larger number of varieties and biological replicates, the anthocyanin composition has the potential to be exploited for classification purposes and for tracing back the cherry biotype in processed products (e.g., cherry juice, jam, flavoured yogurt).

A proteomic analysis in the sweet cherry cultivar 'Hedelfinger' by mass spectrometry was applied in Italy (Prinsi et al. 2016). The study provided the first proteomic characterisation of fruit ripening in the sweet cherry, revealing new positive traits of the somaclonal variant.

The fruit firmness in sweet cherry cultivars was studied in Canada (Stanich et al. 2016), where a principal component analysis showed the seasonal, culti-

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var, treatment, and storage effects among three subsets of cultivars with differing characteristic firmness. The softer early-harvest cultivars had a higher proportion of "too soft" fruit.

The implication of abscisic acid on the ripening and quality in sweet cherries was studied in Spain (Tijero et al. 2016), where it was concluded that abscisic acid plays a major role in the sweet cherry development, stimulating its ripening process and positively influencing the quality parameters during pre-harvest.

The effects of combining an alginate coating and the application of essential oils on sweet cherry properties were studied in Spain (Zapata et al. 2016). According to the results, the combination of the alginate coating with the essential oils was considered a good post-harvest tool to increase the shelf life of sweet cherry cultivars with beneficial effects in terms of increasing the antioxidant potential.

The processes underlying the fruit firmness loss during the life of the sweet cherry cultivar 'Somerset' was evaluated in Spain (Belge et al. 2017). The soluble and insoluble cell wall materials were extracted from the lyophilised tissue and a number of cell wall-modifying enzyme activities were assessed that were apparently connected to the ripening-related firmness changes in this cultivar.

The genoprotective potential of the total anthocyanin extracted from *P. avium* was studied in Turkey (Berber 2017). The total antochyanins extracted from *P. avium* had a reduced micronucleus assay frequency in all the concentrations according to the positive control. In the comet assay, significant decreases in the comet tail length, tail moment and tail intensity were observed in all the concentrations.

A metabolomics analysis and the artificial simplified phytocomplexes reveal the cultivar-dependent synergy between the polyphenols and ascorbic acid in fruits of the sweet cherry in Italy (Commisso et al. 2017), where it was found that the total antioxidant activity of the sweet cherry fruits may originate from cultivar-dependent interactions among different metabolite classes.

The range of the main problems connected with the post-harvest processing technology in the sweet cherry were analysed in China (Cui et al. 2017) which were ranged as follows: (1) unseemly time of harvesting, (2) lagging behind in post-harvest processing technology (including pre-cooking, grading, screening, packaging, transport and storage), (3) incomplete fruit circulation system, (4) lack of brand awareness, and (5) lack of guiding mechanism of associations.

The content of the bioactive and volatile compounds in sweet cherry cultivars was studied in Spain (Domenech et al. 2017), where the most important organic acid was malic acid, and fructose and glucose were found in a greater quantity. The cultivars with the highest antioxidant activity were 'Burlat' and 'Brooks'.

The phenolic profile and biological potential of five varieties of sweet cherries were studied in Portugal (Gonçalves et al. 2017), where it was found that sweet cherries possess a great biological potential, and further investigation should be undertaken to promote the commercialisation and encourage its use in food supplements and in new pharmaceutical and nutraceutical applications.

The content of the bioactive compounds in sweet cherries was studied in Spain (González-Gómez 2017), where the cultivars were characterised for having an important number of bioactive compounds, mostly polyphenols together with indolamines, such as melatonin and serotonin.

An anatomic study of sweet cherry fruits took place in Germany (Grimm et al. 2017). The tracer distribution was studied using light microscopy and magnetic resonance imaging. The vasculature of the sweet cherry comprises five major bundles. Three of these bundles supply the flesh; two enter the pit to supply the ovules. All the vascular bundles branch into major and minor veins that interconnect via numerous anastomoses.

The productive instability of sweet cherry orchards was studied in Chile (Gratacós et al. 2017). The aim of the study was to assess microscopic methods to follow the flowering process and fruit set that allowed discriminating factors causing poor fertilisation. In the dormant stage, pistils and stamens were completely differentiated; the ovules were in the early stages of differentiation; however, the pollen did not initiate this process.

The content of the bioactive compounds in fruits from organic and conventional sweet cherry production was evaluated in Poland (Hallmann, Rozpara 2017). The obtained results showed that the organic sweet cherry fruits contained significantly more total sugars including glucose and fructose, total anthocyanins, especially cyanidin-3.5-di-O-rutinozide, as well as two identified flavonoids: luteolin and quercetin.

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The impact of the flower biology on the fruit set in sweet cherries was studied in Spain (Herrero 2017). In the work, the reproductive process in the cherry was first examined in a positive way, following the steps that go from pollination to fertilisation.

The changes in the carbohydrate levels and relative water content to distinguish the dormancy phases in sweet cherry were studied in Germany (Kaufmann, Blanke 2017). For the first time, the transition points were identified based on the constituents (carbohydrates and relative water content) in the floral buds related to the current chilling status and the dormancy phases were also presented in a schematic diagram.

The optimisation of the osmotic dehydration of the cherry by the response surface methodology was studied in Spain (Martínez-Cañas et al. 2017). The optimal conditions were scaled to a pilot plant, where the results were in agreement with those obtained at the laboratory scale. The resulting material achieved by this process conserved the chromatic properties of the initial product.

The sweet cherry fruit physiology in relation to the dynamic regulation of calcium after foliar sprays application was studied in Greece (Michailidis et al. 2017), where the metabolomic analysis revealed significant alterations in the primary metabolites among the Ca_2 + treatments, including the sugars (e.g., glucose, fructose), soluble alcohols (e.g., arabitol, sorbitol), organic acids (e.g., malate, quinate) and amino acids (e.g., glycine, beta-alanine).

The antioxidant activity and mineral content in the 'Sweetheart' cherry peel were studied in Portugal (Resende et al. 2017). All the nutritional concentrations in the peel were significantly higher than in the remaining fruit, showing its potential for nutritional complementary production.

A review book focused on sweet cherry botany, production and users was written by international researchers in the USA (Quero-García et al. 2017), where the up-to-date scientific data and applied information was presented; the book is invaluable for researchers, teachers and all professionals working in the cherry value chain.

The effects of two dormancy breaking agents on the flowering and ripening in two sweet cherry cultivars were studied in Spain (Rodrigo et al. 2017). The different effects observed between the years in both cultivars treated at the same dates are discussed in terms of the chilling accumulated at each date and the stage of the bud development in which the applications were made.

In vitro multiplication and rooting of two sweet cherry cultivars were studied in the Czech Republic (Sedlak, Paprstein 2017), where the multiplication and rooting rates were sufficient for *in vitro* culture establishment, short-term maintenance and *in vitro* chemotherapy of these cultivars.

The monitoring of the spotted wing drosophila in sweet cherry was performed in the USA (Van Steenwyk et al. 2017). The the most effective and selective bait was apple cider vinegar combined with sake and the most effective trap was a side-screen trap.

The characterisation of the phenolic compounds and antifungal activities of sweet cherries was studied in China (Wang et al. 2017). The results from the study provide further insights into the health-promoting phenolic compounds in sweet cherries.

Whether HC improves the endodormancy release and blooming associated with endogenous hormones in 'Summit' sweet cherry trees was studied in China (Wang et al. 2017). A higher GAs : ABA ratio was observed in the HC-treated 'Summit' branches from the endodormancy release until full bloom. However, a reciprocal pattern occurred thereafter due to the senescence of the flowers.

The effects of gibberellic acid and a new compound, homobrassinolide, application on the harvest and shipping quality of three late-season cultivars grown in the USA was studied (Wang, Einhorn 2017). Homobrassinolide applied at 1 ppm increased the fruit firmness of the 'Sweetheart' cultivar, but did not affect the fruit colour, fruit size, soluble solid content, titratable acidity, pitting susceptibility and skin darkening.

Rootstock impact. The responses of the '0900 Ziraat' sweet cherry variety grafted on mazzard (*P. avium* L.) and mahaleb (*P. mahaleb* L.) rootstocks to salt stress were studied in Turkey (Küçükyumuk et al. 2015). where it was determined that both parameters decreased towards the end of the growing period for all the treatments. The sodium uptake was excluded by the 0900/mahaleb rootstocks, but the chloride uptake was excluded only for higher saline conditions. On the basis of results the mahaleb (*P. mahaleb* L.) rootstock could be recommended to be used as a rootstock for sweet cherry cultures under saline conditions.

The effects of the dwarfing 'Gisela 5' rootstock on the reproductive potential, vegetative growth, and physiological features of some sweet cherry cultivars in high-density sweet cherry orchards was studied in Romania (Popescu, Popescu 2015), where the obtained data from field measurements

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and laboratory observations demonstrated that the 'Gisela 5' rootstock is compatible with foreign sweet cherry varieties under the selected growing area and can be used to achieve high-density sweet cherry orchards.

The rootstock effects on the growth yield and fruit quality of the sweet cherry cv. 'Newstar' was studied in Spain (Lopez-Ortega et al. 2016). The study demonstrated that the rootstocks were decisive in the vigour and yield of the grafted cultivar, as well as the size, acidity, colour and firmness of the fruit.

The influence of four different dwarfing rootstocks on the phenolic acids and anthocyanin content in fruits of the sweet cherry cultivars 'Kordia' and 'Regina' was researched in Croatia (Milinović et al. 2016). In the study, the total phenols and total anthocyanins were determined by spectroscopic methods, while the individual anthocyanins and hydroxycinnamic were quantified and identified by high performance liquid chromatography.

The effects of the nitrogen availability on the root dynamics in 'Bing' on 'Gisela' rootstock sweet cherry trees were studied in Chile (Artacho, Bonomelli 2017). The results indicated that the N application led to sustained root production throughout the growing season.

The recent developments in sweet cherry production were presented in a contribution from Croatia (Biško et al. 2017). In recent years, there were changes in the type of rootstocks: the proportion of vigorous generative rootstocks gradually decreased and the proportion of vegetative, less vigorous ('Colt') and dwarfing rootstocks ('Gisela 5' and 'Gisela 6') gradually increased.

The evaluation of four dwarfing cherry rootstocks combined with 'Kordia' and 'Regina' in the agro-environmental conditions of northwest Croatia was studied (Biško et al. 2017), where the highest cumulated yield efficiency index (0.83 and 0.92) was recorded in 'Gisela 5' and 'Gisela 6' induced the need of trellising, while 'PHL-C' does not need trellising.

The impact of Hungarian bred mahaleb rootstocks on sweet cherry cultivars was evaluated in Hungary (Bujdosó, Hrotkó 2017); the best fruit size was produced by the rootstock 'Érdi V. O'.

The impact of the used rootstocks on the post-harvest properties of sweet cherry fruits was studied in Poland (Dziedzic et al. 2017), where the rootstocks significantly influenced the fruit quality parameters after storage. The findings of the research on how the rootstocks affect the sweet cherry fruit properties can be useful for sweet cherry breeding programmes, as well as for sweet cherry crop production and storage technologies.

The effect of eight different rootstocks on the agronomic and fruit quality parameters of the 'Van' and 'Stark Hardy Giant' sweet cherry cultivars was evaluated in Spain (Forcada et al. 2017). 'Van' trees on 'Adara' and 'SHG' on 'MaxMa 14' showed the highest vigour whereas the lowest values were shown by 'Gisela 5' for both cultivars. The cumulative yield was the highest on the 'Adara' rootstock for the 'Van' cultivar.

The effects of the rootstock and training system on the fruit quality of new sweet cherry cultivars were studied in Italy (Grandi, Lugli 2017). The results showed that 'Gisela 6' positively affected the early bearing and yield levels up to year 4, whereas by year 5, the yield levels with 'Colt' and the multi-leader system reached those of 'Gisela 6'.

A breeding programme for sweet cherry rootstocks realised in Chile (Guajardo et al. 2017) involved the interspecific cross of *P. avium* ($2n = 16$) × *P. cerasus* ($4n = 32$), where the 26 obtained seedlings resulted, as expected, in triploid hybrids ($3n = 24$). The results were useful in both making the programme more cost-effective and allowing for the better planning of interspecific crosses.

Pre-selection methods for testing rootstocks were developed in Serbia (Ognjanov et al. 2017). Based on the tree parameters, a pre-selection model of cherry dwarfing potential, as well as a methodological procedure for successive breeding phases, was proposed.

The influence of the rootstock on the growth and fructification of cherry cultivars in a high-density cultivation system was studied in Romania (Pal et al. 2017). The rootstocks influenced the height of the trees, the shoot growth, the number of the long and fruiting branches, the trunk cross sectional area yield and precocity, with differences statistically assured.

The influence of the heading heights of the tree leader on the growth and fruiting of sweet cherries using the 'Burlat', 'Bing' and 'Van' cultivars on the 'Gisela 5' rootstock was studied in Bulgaria (Radomirska, Domozetova 2017). The highest net incomes were obtained for the trees shortened to 70 cm in height of the stem.

The effects of five clonal rootstocks on the 'Sylvia' and 'Karina' sweet cherry cultivars were studied in Poland (Sitarek 2017). The rootstock effects on the yield efficiency were consistent between the two

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cultivars, with the most yield efficient trees were obtained on 'Gisela 3', 'Gisela 5' and 'Weiroot 72' whereas the least efficient ones were the trees on 'F12/1'.

The sweet cherry rootstock impact on cultivars was studied in Bulgaria (Sotirov 2017). Trees on the 'SL-64' rootstock had the highest root-suckering ability.

The evaluation of five rootstocks with the cherry cultivars 'Kordia' and 'Regina' was performed at two locations in Slovenia (Usenik et al. 2017), where the cumulative yield for both locations and both cultivars were significantly affected by the rootstock as follows: 'Gisela 6' > 'Gisela 5' ≥ 'Piku1' ≥ 'Weiroot 158' > 'PHL-C'.

The indole-3-butyric acid effects on a sweet cherry rootstock 'Gisela 6' softwood cutting rooting were studied in China (Wei et al. 2017). The results indicated that indole-3-butyric acid increased the rooting activities of 'Gisela 6' softwood mainly owing to the increase in the activities of the polyphenol oxidase and peroxidase, the total soluble sugar concentration and the reduction of the indoleacetic acid oxidase activity.

Storage quality. The influence of the post-harvest chitosan treatment on sweet cherry fruits was studied in Italy (Pasquariello et al. 2015). A multivariate statistical approach including a principal component analysis provided a global view of the response of the three studied sweet cherry cultivars to the chitosan coating and storage temperature. The chitosan-coated fruit showed a lower decay both at 2 °C and 24 °C than the uncoated fruit.

The effects of 1-methylcyclopropene on the quality of sweet cherry fruits during storage were studied in Italy (Piazzolla et al. 2015). After six days at 20 °C, the treated fruits showed a lower weight loss and respiration rate compared to the untreated cherries. In the cherries stored at 4 °C for 13 days, 1-methylcyclopropene was only effective in slowing down the respiration rate and delaying the peduncle deterioration, whereas no other differences were detected between the treated and untreated fruits.

The application of post-harvest methyl salicylate treatments on sweet cherry fruits was studied in Spain (Giménez et al. 2016). The treatments delayed the ripening of the fruits during storage with enhanced concentration of the bioactive compounds and antioxidant activity.

The enhancement of the storage quality of harvested sweet cherry fruit by immersion with β-aminobutyric acid was studied in China (Wang et al. 2016). The results showed that treated cherries had lower respiration rates and weight loss and higher levels of titratable acidity, total phenolics, ascorbic acid, fructose, glucose, sucrose, malic, citric and succinic acids compared with that in the control fruit.

The electronic program Cherry was developed in Chile for detection in post-harvest operations with sweet cherries (Bro, Rojas 2017). The program Cherry was found to detect low magnitude accelerations that might cause damage during the transport and processing of sweet cherries.

The control of post-harvest diseases in sweet cherries was studied in Spain (Delgado-Adámez et al. 2017). The application of microbial antagonists in combination with sodium bicarbonate was the most effective. Thus, the combination of microbial antagonists and sodium bicarbonate could be an alternative to chemicals for the control of post-harvest rot on cherries.

The effect of the sweet cherry post-harvest treatment with calcium was studied in Spain (Díaz-Mula et al. 2017). The application of calcium solutions could be a good tool for the post-harvest application with the aim to retard the post-harvest ripening process of the sweet cherry and, in turn, to extend the storability of this perishable fruit. Interestingly, at the end of storage, the treated cherries showed a higher antioxidant activity, in both the hydrophilic and lipophilic fractions than the control fruits.

The impact of the pre-harvest salicylic acid and acetylsalicylic acid treatments in order to preserve the quality and enhance the antioxidant systems during the post-harvest storage of sweet cherry cultivars was studied in Spain (Giménez et al. 2017). Upon the results of the study, both the salicylic acid and acetyl salicylic acid pre-harvest treatments could be promising tools for improving the sweet cherry quality at harvest and after storage, with an additional effect on delaying the post-harvest ripening process by increasing the levels of antioxidant compounds and the activity of the antioxidant enzymes.

Sweet cherries from farm to table were reviewed in India (Habib et al. 2017), where it was stated that properly designed modified atmospheric packs can be exploited to lower the respiration rates and, thus, the ripening of fruits which results in least amount of changes in the physiochemical parameters of sweet cherries during the post-harvest storage. The paper intended to review a broad spectrum of studies dealing with the use of modified atmospheric packs for the preservation of sweet cherry cultivars with an interest in future research work.

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The effects of post-harvest UV-C and edible coating treatments on the fruit quality and storage of sweet cherry were evaluated in Turkey (Koçak, Bal 2017). The storage period could be longer in the MAP, UV-C + Chitosan, UV-C + Alginat and UV-C + MAP treated fruits.

The effect of an aloe vera gel treatment on the bioactive compounds and antioxidant activity during storage of sweet cherries was studied in Spain (Serrano et al. 2017). In the research, it was concluded that the use of an aloe vera gel, as an edible coating, could be an innovative and natural tool to preserve the sweet cherry quality during storage, without any detrimental effect on the content of the bioactive compounds or antioxidant properties.

The effect of a modified atmosphere on the post-harvest quality of 'Sweetheart' sweet cherry fruits was studied in Spain (Tapia García et al. 2017). The weight loss was reduced by using modified atmosphere packaging. As compared with the control cherries, the fruits packed in the modified atmosphere packaging had higher firmness, better colour maintenance and overall appearance. Stem browning was reduced after 2–3 weeks of cold storage in the modified atmosphere packaged fruits.

The respiration rates of sweet cherry cultivars during fruit storage were studied in Canada (Toivonen, Hampson 2017). The respiration rates of several cultivars were measured at 0, 5 and 10 °C and a principal components analysis was used to group the cultivars with similar response patterns. Most cultivars clustered together when the respiration was measured at 0 °C except several clustered together when measured at 5 and 10 °C.

Tree training. Protective growing systems in sweet cherry orchards were studied in USA (Lang et al. 2016). The research was focused on increasing the protected environmental space efficiencies through the complementary development of suitable high-density training systems and a fixed solid-set (vs. tractor-based) spray technologies. Multiple potential benefits and limitations for each protective covering system and associated complementary orchard technologies were then summarised.

A parallel Trident planting system in sweet cherry orchards was evaluated in Romania (Stănică et al. 2016). The parallel Trident appeared to be a suitable for medium-density sweet cherry orchards with semi-vigorous and semi-dwarfing rootstocks.

The effects of three sweet cherry tree training systems (multi-leader bush, Vogel Central Leader and a tri-axe) using 'Bing', 'Regina', and 'Sweetheart' cultivars grafted onto three different rootstocks ('Mazzard', 'MaxMa 14' and 'Gisela 6') was evaluated in the USA (Long et al. 2017). The yields were the highest with the Vogel Central Leader training system, but fruit size was similar across all three systems.

The interaction of the training system and rootstock on the yield, fruit size, fruit quality and crop value of three sweet cherry cultivars was studied in the USA (Robinson et al. 2017). The Vertical Axis system had the highest cumulative yield per ha, while the cumulative yield efficiency and cumulative crop value were followed by the Central Leader, Spanish Bush and Quad Axis. The cumulative yields and crop value were positively related to the planting density. The fruit size was largest with the Quad Axis and the Central Leader, was smaller with the Spanish Bush, and the smallest with the Vertical Axis.

The V-system and UFO-system of sweet cherry tree trading were compared in Belgium using the cultivars 'Kordia' and 'Sweetheart' on a 'Gisela 5' rootstock (Vercammen, Gomand 2017). The UFO-system was very labour-intensive because the time required for tying. In the first years, the yield from the trees trained in the V-system was 50% higher than for the trees trained to the UFO-system. The fruit size, on the other hand, was almost the same for both systems.

The number of citation items in the evaluated years is illustrated by Table 1. There from the total of 199 citation items the most (122) were published in 2017 whereas the least (35) were published in 2015. The number of citations in 2016 was only by 7 items higher.

The number of citation items according to countries is presented in Table 2. Thre from total of 33 countries the most items (23) were published in USA. In the following order are ranged by Italy (18), Chile (17), China (16) and Spain (14). On the contrary only one citation item was coming from Denmark, Georgia, India, Macedonia, New Zealand and Ukraine.

Table 1. Number of citations in the evaluated years

Year	Number
2015	35
2016	42
2017	122
Total	199

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Table 2. Number of citations in the countries

No.	Country	Items	No.	Country	Items
1	Australia	7	17	Japan	3
2	Belgium	4	18	Korea	2
3	Bulgaria	6	19	Macedonia	1
4	Canada	5	20	New Zealand	1
5	Chile	13	21	Norway	2
6	China	16	22	Poland	6
7	Croatia	2	23	Portugal	8
8	Czech Republic	7	24	Romania	3
9	Denmark	1	25	Serbia	3
10	France	2	26	Slovenia	2
11	Georgia	1	27	Spain	34
12	Germany	6	28	Turkey	13
13	Greece	4	29	Ukraine	1
14	Hungary	2	30	United Kingdom	2
15	India	1	31	USA	23
16	Italy	18		Total	199

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