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# Factors influencing fruit set and quality in different sweet cherry cultivars

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## Abstract

The aim of this work is the characterisation of seven cultivars of sweet cherry grown at Murcia (Spain) by determining flower bud density, flower buds drop, number of developing flower buds and total number of flowers per node, fruit set and percentage of double fruits from 2004 to 2007. Also some attributes related to fruit quality, such as fruit weight, colour, soluble solids, total acidity and firmness were evaluated at different ripening stages. 'Brooks' shows high production of flower buds and an appropriate total number of flowers per node in different years, besides high levels of total soluble solids (TSS), ripening index and fruit firmness. 'Burlat' and 'Somerset' ranged medium values of most of the analyzed floral biology and fruit quality parameters. 'Cristobalina' had high fruit set percentages in all years of study (34-42 %), but the fruit size (7.26 ± 0.30 g) and the fruit firmness values were low (1 N $mm^{-1}$). The maturation period of 'Marvin' fruits was very short and at the commercial ripening stage these fruits showed the darkest red colour. In 'Ruby' the fruit set was very erratic and the percentage of double fruits was high. This cultivar presented a good ripening index and fruit firmness levels. 'New Star' is characterized by consistent high fruit set percentages (35-65%), absence of double fruits as well as by good fruit size (12.7 ± 0.54 g), colour and firmness levels (≈2 N $mm^{-1}$).

**Additional key words**: breeding; flower buds; fruit quality; fruit set.

## Resumen

### Factores que afectan al cuajado y la calidad del fruto en distintas variedades de cerezo

En este trabajo se ha realizado la caracterización pomológica de siete variedades de cerezo, cultivadas en la Región de Murcia. Se han determinado características florales como densidad de yemas de flor, número de yemas de flor y número total de flores por ramillete, caída de yemas, porcentaje de cuajado de frutos y de frutos dobles desde 2004 hasta 2007. También se determinaron algunos atributos relacionados con la calidad de las cerezas, como peso, color, sólidos solubles, acidez total y firmeza. La variedad 'Brooks' además de mostrar una elevada producción de yemas florales y un número adecuado de flores por ramillete, registró altos niveles de sólidos solubles totales, índice de madurez y firmeza. 'Burlat' y 'Somerset' alcanzaron valores medios en la mayoría de los parámetros de biología floral y calidad de fruto analizados. En 'Cristobalina' el porcentaje de cuajado de frutos fue elevado en todos los años de estudio (34-42%), aunque el tamaño de la cereza (7,26 ± 0,30 g) y sus valores de firmeza (1 N $mm^{-1}$) fueron muy bajos. 'Marvin' presentó un porcentaje de frutos dobles bajo, un período de maduración bastante corto y fue la variedad que presentó el color rojo más oscuro. En 'Ruby' el cuajado de frutos fue muy errático y la presencia de frutos dobles importante. Esta variedad registró un buen índice de madurez, así como buena firmeza. 'New Star' destacó por los elevados porcentajes de cuajado (35-65%) y ausencia de frutos dobles, además de buen tamaño de los frutos (12,7 ± 0,54 g), color y elevada firmeza (≈2 N $mm^{-1}$).

**Palabras clave adicionales**: calidad del fruto; cuajado; mejora genética; yemas de flor.

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Abbreviations used: TA (total acidity), TSS (total soluble solids).

# Introduction

Sweet cherry (*Prunus avium* L.) is one of the most appreciated fruit by consumer due to its excellent quality. Spain is one of the main cherry producers in Europe, with production of 75,738 t in 2007, which represents 14% of the total in the European Union (MARM, 2008). This is an interesting alternative crop in southeast of Spain because it is complementary to apricot, plum or early peach. This species needs less water and nitrogen supply than other tree crops and it is tolerant to *Plum pox virus* (Sharka), which is an important problem in apricot, peach and plum.

In the last years, many new cultivars have been released from different breeding programmes all over the world. The interest of breeders is diverse but the knowledge of different aspects such as floral biology, fruit set behaviour or fruit quality of each cultivar could help them to choose the appropriate cultivars to be grown in a particular area with specific climatic conditions or as parentals in a breeding program. There are many factors related to floral biology of fruit trees that influence productivity, such as flower bud density, flower bud drop, flower quality or fruit set. Although problems related to poor yields are frequently found in some sweet cherry cultivars, there are few studies on floral biology that could help to better understand the cause of these problems. Thus, in different cultivars of *Prunus* species such as apricot or sour cherry, the influence of weather conditions on pollination, ovule longevity and fruit set has been studied in many fruit varieties (Guerriero *et al.*, 1985; Furukawa and Bukovac, 1989; Burgos and Egea, 1993). Also the flower bud production has been studied in several cultivars of peach and nectarine (Bellini and Gianelli, 1975; Okie and Werner, 1996) or apricot (Alburquerque *et al.*, 2004; Ruiz and Egea, 2008).

Other factor that may have a negative effect on fruit production and yield is the flower bud drop. Although the causes for high percentages of flower bud drop appear diverse (climatic conditions, chilling requirements, frost, etc.), this trait has been found as genotype-dependent in some apricot cultivars (Legave, 1975; Legave *et al.*, 1982; Alburquerque *et al.*, 2004; Ruiz and Egea, 2008). Particularly in sour or sweet cherry there are some components that contribute to fruit set and yield, such as the number of flowers per bud and the number of flowering nodes per branch (Iezzoni and Mulinix, 1992). Early drop of flowers is a normal process in many species (Guitian, 1993), which decreases fruit set, being an important factor on determining the final yield of fruit species. The influence of different factors such as climatic conditions or genotype on fruit set has been studied in different fruit crops including sweet cherry (Caprio and Quamme, 1998; Hedhly *et al.*, 2003; Alburquerque *et al.,* 2004; Choi and Andersen, 2001).

Sweet cherry is highly appreciated by consumers due to its excellent quality. Although the concept of «fruit quality» depends on the product itself and the consumer's preferences, it is widely accepted that the main characteristics related to sweet cherry quality are fruit weight, colour, firmness, sweetness, sourness, flavour and aroma with important differences among cultivars (Romano *et al*., 2006; Díaz-Mula *et al*., 2009). Thus, fruit quality parameters, together with floral biology aspects, are important factors to be taking into account to choose parentals for a breeding programme.

In this study, seven sweet cherry cultivars, including one local variety, were chosen as representative of different flowering times and productivity to analyse the influence of the cultivar on flower buds production, the number of flower buds per node, flower buds drop, the total number of flowers per node and fruit set. These variables were studied to establish their variability and effect on crop productivity. In addition, some attributes related to fruit quality such as colour changes, the soluble solids content, total acidity and firmness were analyzed at different ripening stages.

# Materials and methods

## Plant material

The sweet cherry cultivars assayed were 'Brooks', 'Marvin' (also called '4-70'), 'Ruby' (California-USA), 'Burlat' (France), 'New Star' (Canada), 'Somerset' (New York-USA) and 'Cristobalina' (Spain). The cultivars were chosen because they span the range of flowering time when cultivated in Murcia (South-East Spain) under the Mediterranean climate. All the cultivars were grown in an experimental field located at Jumilla, with the exception of 'Cristobalina', which was grown in a private orchard located at Abarán and all of them were grafted on 'SL-64' (*Prunus mahaleb* L.) rootstock. Cultivars were planted in 1999 and planting distance was 5 × 3 m. The averages of the annual production during the 2004-2007 period were 18-20 kg tree$^{-1}$ for 'Marvin', 20-25 kg tree$^{-1}$ for 'Burlat' and 'Brooks', 30-35 kg tree$^{-1}$ for 'Somerset', 35-40 kg tree$^{-1}$ for 'Ruby' and 'New Star' and more than 40 kg tree$^{-1}$ for 'Cristobalina'.

**Table 1.** Average maximum and minimum temperatures (°C), rainfall and chill units calculated by Utha method (Richardson *et al.,* 1974) in Jumilla and Abarán (Murcia) during four consecutive years

| | Maximum temperature (°C) | Minimum temperature (°C) | Rainfall (mm) | Chill units |
|---|---|---|---|---|
| *Jumilla* | | | | |
| 2004 | 25.7 | 8.4 | 286.0 | 1,025.0 |
| 2005 | 26.2 | 5.9 | 88.4 | 1,208.0 |
| 2006 | 26.7 | 6.3 | 207.3 | 1,247.5 |
| 2007 | 25.5 | 7.5 | 292.8 | 1,107.5 |
| *Abarán* | | | | |
| 2004 | 27.9 | 10.5 | 256.9 | 678.0 |
| 2005 | 26.7 | 8.3 | 186.2 | 1,132.5 |
| 2006 | 27.2 | 8.3 | 245.0 | 1,004.5 |
| 2007 | 26.1 | 10.5 | 288.7 | 779.0 |

'New Star' and 'Cristobalina' are self-compatible and the rest are self-incompatible, although they have overlapping blooming periods, showing genetic compatibility with each other.

## Culture conditions

Hourly temperatures were provided by the *Servicio de Información Agraria de Murcia* (SIAM; http://www.carm.es/cagr/cida/indexsiam.html). The meteorological stations were located in the experimental field at Jumilla and very close to the private orchard at Abarán. Table 1 shows average maximum and minimum, rainfall and total chill units at the sampling sites from 2004 to 2007. Chilling requirements, flowering and harvest time were recorded for all cultivars in Jumilla and Abarán during two consecutive years (2004 and 2005, Table 2).

**Table 2.** Full blooming dates (50% of flowers completely open) and harvest dates (commercial ripening stage, S4). Data are average from two consecutive years (2004-2005) for blooming and harvest days

| Cultivar | Blooming date | Harvest date |
|---|---|---|
| 'Cristobalina' | March 14th | April 18th |
| 'Brooks' | March 27th | May 12th |
| 'Ruby' | March 29th | May 10th |
| 'Somerset' | April 3rd | May 20th |
| 'Burlat' | April 4th | May 3th |
| 'New Star' | April 4th | May 17th |
| 'Marvin' | April 9th | May 7th |

In both experimental fields the irrigation treatments were carried out using a drip irrigation system with two emitters (each delivering 4 L $h^{-1}$) per tree. Total water amounts applied were 3,675 $m^3$ $ha^{-1}$ and the fertilization doses were 50 kg $ha^{-1}$ of nitrogen, 80 kg $ha^{-1}$ of phosphorus and 120 kg $ha^{-1}$ of potassium (33.5% N, 18% $P_2O_5$ and 46% $K_2O$).

## Experimental design

The experimental orchards contained six trees of each cultivar in a completely randomised design. Three trees per cultivar were randomly chosen. Two branches with 'bouquets of May' inserted on two years old wood of similar size per tree were selected and marked after fall defoliation. At the stage B (Baggiolini, 1952, modified by Lichou *et al.*, 1990) when the flower buds were easily identified, «flower bud density» was recorded in the six chosen branches and expressed as number of flower buds per cm of branch, in order to measure flower bud production. Total number of flower buds at stage D (Lichou *et al.*, 1990) was also recorded, as well as the percentage of dropped flower buds in those branches (flower buds drop). The number of flower bud per node or per «bouquet of May» was determined and, due to the different number of flowers that have cherry flower buds, total number of flowers per node or per «bouquet of May» was determined at bloom (when flowers were opened). Fruit set percentage was calculated as the number of fruits at harvest date per total flowers at bloom (Alburquerque *et al.*, 2004). Also the percentage of double fruits was determined in ‘Brooks’, ‘Burlat’, ‘Marvin’, ‘New Star’, ‘Ruby’ and ‘Somerset’ as the number of double fruits per total number of fruits in six different branches of each cultivar, which had at least 50 fruits.

Flower bud density, flower buds drop, number of flower buds per node, total number of flowers per node and fruit set were observed during three consecutive years (2005, 2006 and 2007) for all cultivars and also in 2004 for ‘Brooks’, ‘Marvin’ and ‘Ruby’ cultivars. The percentage of double fruits and cracking sensitivity was recorded in 2005, 2006 and 2007 for all cultivars, with the exception of ‘Cristobalina’.

### Fruit quality attributes

For each cultivar 18 homogeneous fruits were harvested at four ripening stages (S1 to S4), according to fruit colour and size. Cherry fruit at S1 were in the last growth phase having a light red colour, while at S4 they have reached the commercial ripening stage to be harvested. Thus, S1-S4 corresponded to S11-S14 stages described for cherry fruit growth and ripening on tree by Serrano *et al.* (2005a). Fruit weight, firmness, and colour were measured individually in each fruit, and data are the mean ± SE (n = 18). Then, three subsamples of 6 fruits were made at random, and then the edible portion was cut in small pieces to obtain 3 homogenous subsamples for each cultivar and ripening stage, in which soluble solid content (TSS) and total acidity (TA) were determined. The weight for each fruit was determined using a digital balance (ST-360 Gram Precision, Spain) with two significant figures and results were the mean ± SE. Fruit firmness was determined using a TX-XT2i Texture Analyzer (Stable Microsystems, Godalming, UK) interfaced to a personal computer, with a flat steel plate mounted on the machine. For each fruit, the cheek diameter was measured and then a force that achieved a 3% deformation of the fruit diameter was applied. Results were expressed as the ratio between this force and the covered distance ($N\ mm^{-1}$) and were the mean ± SE. This determination of firmness as the slope of the force-deformation curve has been chosen as the most characteristic attribute for textural changes in cherry fruits (Serrano *et al*., 2005a; Muskovics *et al*., 2006). Three colour determinations were made on each fruit at 120° interval along the equatorial perimeter using the Hunter Lab System (L*, a*, b*) in a Minolta colorimeter CR200 model (Minolta Camera Co., Osaka, Japan). TSS was determined in duplicate from the juice obtained from each subsample with a digital refractometer Atago PR-101 (Atago Co. Ltd., Japan) at 20°C and results expressed as the mean ± SE in °Brix. TA was determined from the above juice by potentiometric titration with 0.1 N NaOH (0.998 factor) up to pH 8.1, using 1 mL of diluted juice in 25 mL distilled $H_2O$ according to Serrano *et al.* (2009). Results were the mean ± SE expressed as g of malic acid equivalent 100 $g^{-1}$ fresh weight.

### Statistical analysis

Data of flower bud density, flower buds drop, number of flower buds and total number of flowers per node, fruit set, percentage of double fruits, the colour determinations, the soluble solids, total acidity and firmness were statistically analysed by the general lineal model (GLM) using SAS GLM version 8 (SAS Institute Inc., Cary, NC, USA). Percentages were transformed by arcsine root square and ANOVA analysis was carried out. When necessary, a LSD test was used to determine differences between treatment means.

## Results and discussion

Full blooming dates (50% of flowers completely open) and harvest dates (commercial ripening stage) were recorded for all cultivars in the experimental fields, and average values from 2004 and 2005 are presented in Table 2. The latest cultivar to bloom was ‘Marvin’, which is the cultivar with more chilling requirements (1,001 chill units, Alburquerque *et al*., 2008). On the contrary, ‘Cristobalina’ had the lowest chilling requirements among the studied cultivars (397 chill units, Alburquerque *et al.*, 2008) and it flowered at middle March. However, harvest time was not related to blooming time, since it varied from middle April for the earlier cultivar ‘Cristobalina’, which was the earliest cultivar to flower, to middle-late May for ‘Somerset and ‘New Star’, whereas the later cultivar to flower (‘Marvin’) was harvested at early May.

### Flower bud density

Flower bud density was not significantly different between cultivars (Table 3 and Fig. 1), suggesting that

**Table 3.** *p* values obtained in the ANOVA for different flowering and fruits quality variables in seven sweet cherry cultivars grown in southeast of Spain recorded in four consecutive years (2004-2007)

| Source of variation | Degrees of freedom | *p* | Source of variation | Degrees of freedom | *p* |
|---|---|---|---|---|---|
| *Flower bud density* | | | *Fruit weight* | | |
| Year | 3 | 0.0001 | Stage | 3 | 0.0001 |
| Cultivar | 6 | 0.2714 | Cultivar | 6 | 0.0001 |
| Year × cultivar | 14 | 0.0107 | Stage × cultivar | 18 | 0.0001 |
| Error | 120 | | Error | 160 | |
| *Number of flower buds/node* | | | *Color index* | | |
| Year | 3 | 0.0001 | Stage | 3 | 0.0001 |
| Cultivar | 6 | 0.0001 | Cultivar | 6 | 0.0001 |
| Year × cultivar | 14 | 0.0001 | Stage × cultivar | 18 | 0.0001 |
| Error | 902 | | Error | 57 | |
| *Flower buds drop* | | | *Soluble solids* | | |
| Year | 3 | 0.0057 | Stage | 3 | 0.0001 |
| Cultivar | 6 | 0.0890 | Cultivar | 6 | 0.0001 |
| Year × cultivar | 14 | 0.0001 | Stage × cultivar | 18 | 0.0001 |
| Error | 117 | | Error | 104 | |
| *Total number of flowers/node* | | | *Total acidity* | | |
| Year | 3 | 0.0001 | Stage | 3 | 0.0001 |
| Cultivar | 6 | 0.0001 | Cultivar | 6 | 0.0001 |
| Year × cultivar | 14 | 0.0001 | Stage × cultivar | 18 | 0.0001 |
| Error | 902 | | Error | 104 | |
| *Fruit set* | | | *Ripening index* | | |
| Year | 2 | 0.0001 | Stage | 3 | 0.0001 |
| Cultivar | 8 | 0.0001 | Cultivar | 6 | 0.0001 |
| Year × cultivar | 14 | 0.0006 | Stage × cultivar | 18 | 0.0001 |
| Error | 120 | | Error | 104 | |
| *Double fruits* | | | *Fruit firmness* | | |
| Year | 2 | 0.2845 | Stage | 3 | 0.0001 |
| Cultivar | 5 | 0.0001 | Cultivar | 6 | 0.0001 |
| Year × cultivar | 10 | 0.0161 | Stage × cultivar | 18 | 0.0001 |
| Error | 134 | | Error | 288 | |

the flower bud density is not a genotype-dependent factor in sweet cherry. However, a clear influence of genotype on flower bud production has been observed in peach and nectarine (Okie and Werner, 1996) as well as in some apricot cultivars (Alburquerque *et al.,* 2004; Ruiz and Egea, 2008).

Flower bud production was different among years. Contrary, flower bud density within apricot cultivars was not significantly affected by the year (Alburquerque *et al*., 2004), although the climatic conditions were very different between years. The influence of the year observed in sweet cherry could be due to the fact that sweet cherry is more sensitive to temperature profiles during flower bud induction than other fruit species. Furthermore, the effect of the year on flower bud density was different for each variety, with the exception of 'Brooks', 'Burlat' and 'New Star'. Flower bud density of 'Marvin' was smaller in 2004 than in others years. For 'Cristobalina', 'Ruby' and 'Somerset' the higher flower bud production was observed in 2006. These results indicate that the effect of year on flower bud density is more accused in some cultivars than others.

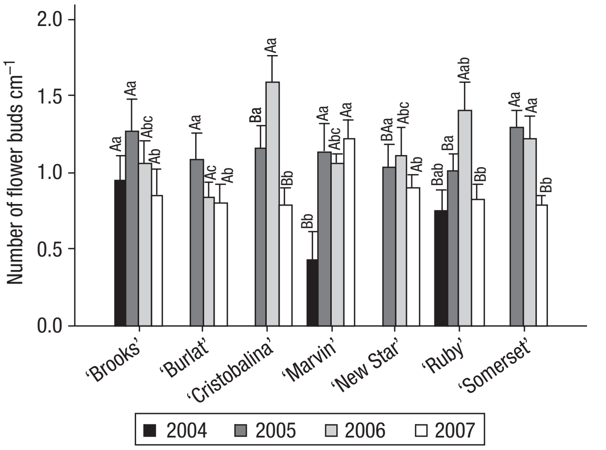


**Figure 1.** Flower bud density (number of flower buds cm$^{-1}$) found in seven sweet cherry cultivars from 2004 to 2007. Data are average ± SE. Different capital letters represent differences between years for the same cultivar and lower-case letters represent differences between cultivars within the same year at 0.05 probability level (LSD test).

## Number of flower buds per node and flower buds drop

The year and the cultivar significantly affected the number of flower buds per node (Table 3). The cultivars 'Brooks', 'Cristobalina', 'Marvin' and 'Ruby' showed the highest production of flower buds per node in the different years and for most of the cultivars this production was slightly high in 2006 (Fig. 2). Accordingly, Iezzoni and Mulinix (1992) found a high variability in the number of flower buds per node when they studied a sour cherry seedling collection.

Flower buds drop percentage was no different between cultivars, but a strong influence of the year was observed (Table 3). The highest percentages of bud drop were observed in 2004 and 2005 (Fig. 2). The interaction between cultivars and years was very significant, which is due to the different values of flower bud drop for each cultivar in different years. Flower bud abscission ranged between 0% ('Burlat' in 2007) and 31.82% ('New Star' in 2006) (Fig. 2). Percentages of flower buds drop of sweet cherry cultivars recorded in this work are much lower than those observed in several apricot cultivars (Martínez-Gómez *et al.,* 2002; Alburquerque *et al.,* 2004; Ruiz and Egea, 2008), although there is not available information about flower buds drop in others sweet cherry cultivars for comparative purposes.

## Total number of flowers per node and fruit set

The statistical analysis of data indicates that cultivar and year had a strong influence on the total number of flowers per node (Table 3). In all cultivars the highest production of flowers per node was observed in 2006, with five cultivars ('Ruby', 'Brooks', 'Marvin', 'Cristobalina' and 'Somerset') having more than 15 flowers per node in this year (Fig. 3).

Fruit set percentages were also strongly influenced by cultivar and year (Table 3), being 'New Star' and

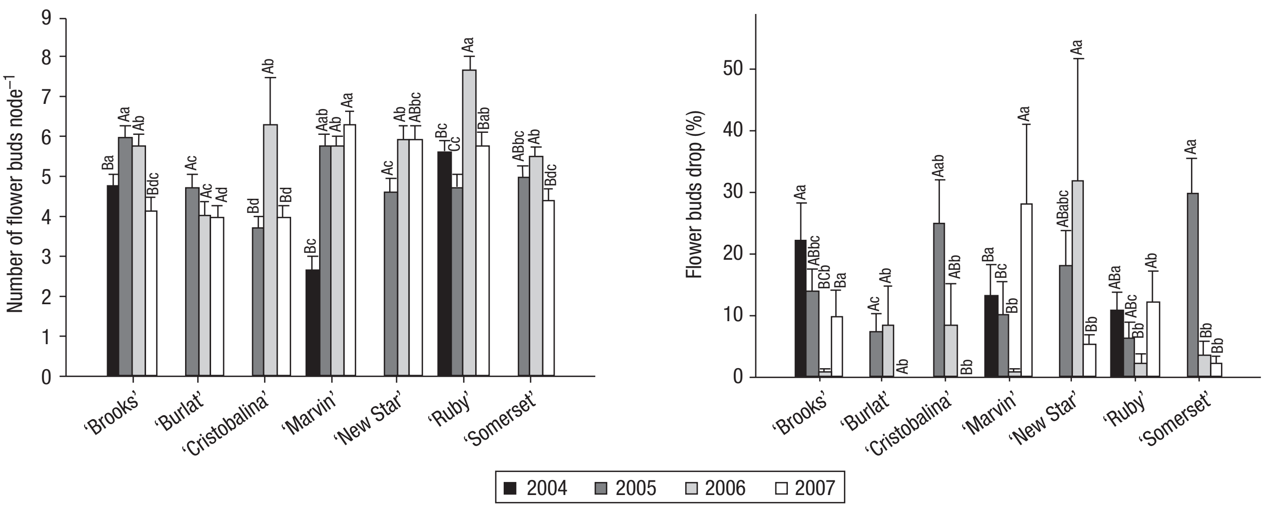


**Figure 2.** Number of flower buds per node and percentage of flower buds drop found in seven sweet cherry cultivars from 2004 to 2007. Different capital letters represent differences between years for the same cultivar and lower-case letters represent differences between cultivars within the same year at 0.05 probability level (LSD test).

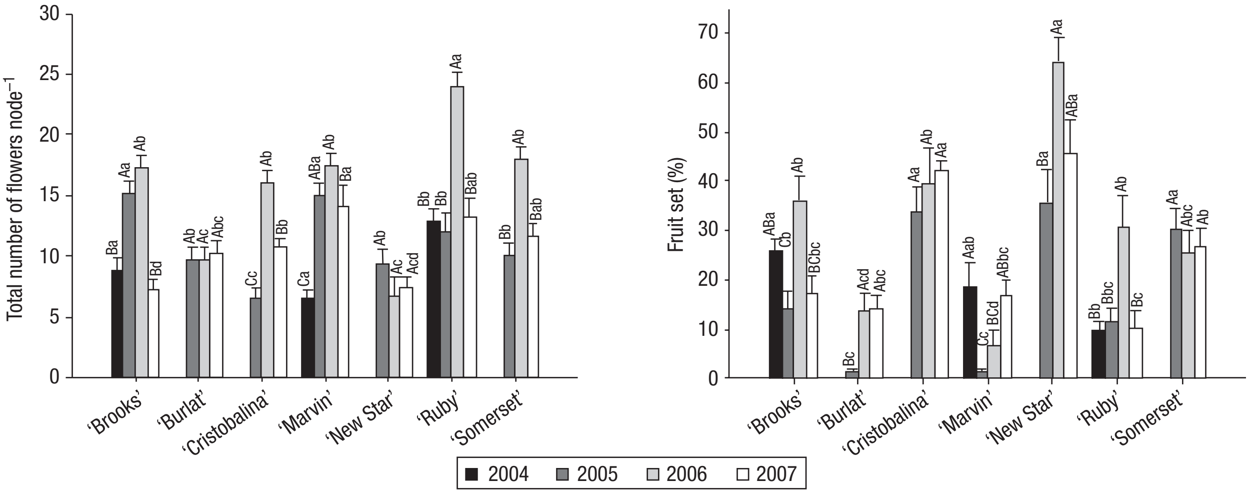


**Figure 3.** Total number of flowers per node and fruit set (%) found in seven sweet cherry cultivars from 2004 to 2007. Different capital letters represent differences between years for the same cultivar and lower-case letters represent differences between cultivars within the same year at 0.05 probability level (LSD test).

'Cristobalina' the cultivars with the highest fruit set in 2005, 2006 and 2007 (over 30 %) (Fig. 3). In addition, there was a strong influence of the interaction cultivar and year on fruit set. Percentages in all cultivars with the exception of 'Cristobalina' and 'Somerset' varied with the year. However, a slightly increase of fruit set percentages was recorded in 2006 in many of the cultivars.

Many studies have examined the influence of climatic conditions at flowering on fruit set with detrimental effect of both, low and high temperatures. Thus, it is known that cold temperatures at flowering reduce the rate of pollen tube growth and may shorten the effective pollination period (Sanzol and Herrero, 2001), while a negative effect of high pre-blossom temperatures (≥ 27°C) on ovule longevity and pollination effectiveness was pointed out by Caprio and Quamme (1998) as causing poor production in apple. The effect of high temperatures during flowering on pollen and pistil functions has been evaluated in detail in sweet cherry. Thus, Postweiler *et al.* (1985) described a negative effect of high temperatures on ovule viability. The duration of stigma receptivity was reduced at temperatures higher than 10°C (20 and 30°C) and pollen germination was also negatively affected at these temperatures (Hedhly *et al.,* 2003). Hedhly *et al.* (2004) studied the pollen tube dynamic in two sweet cherry cultivars founding a differential genotypic response to temperature, since high temperature (30°C) increased the number of pollen tubes at the base of the style in 'Cristobalina' but it was reduced in 'Sunburst', which is adapted to a cooler climate. These results suggest that temperature during flowering could be a selective agent influencing positively pollen tube growth in those genotypes better adapted to warm climatic conditions. The high fruit production observed in 'Cristobalina' could reflect its adaptation to Mediterranean climatic conditions. However, the Canadian cultivar 'New Star' with high chilling requirements (909 chill units, Alburquerque *et al.*, 2008) had very high fruit set percentages. Therefore, differences in fruit production observed between 'New Star', 'Cristobalina' and the rest of cultivars could be due to their self compatibility status.

The year-to-year variation and differences among cultivars seem to indicate that there is a strong influence of climatic conditions and genotype on sweet cherry fruit set, as has been found in other studies (Choi and Andersen, 2001) and in different fruit species such as pear (Atkinson and Taylor, 1994; Atkinson and Lucas, 1996) or apricot (Alburquerque *et al.,* 2004; Ruiz and Egea, 2008).

## Double fruits and cracking sensitivity

The percentages of double fruits were different between cultivars but not between years when averages of all cultivars are compared (Table 3). However, the interaction between cultivars and years was significant (Table 3), which means that the effect of the year on the double fruits production was different for some cultivars.

In `Satohnishiki' sweet cherry cultivar double fruit production has been related to high temperatures during summer, when the sepal and petal differentiation occurs (Beppu *et al.*, 2001). Under our climatic conditions, summer temperatures do not influence equally the production of double fruits. Thus, the percentage of double fruits in 'Brooks' was higher in 2005 (9.8 ± 3.60) than in 2006 (0.7 ± 0.66) or 2007 (0.0 ± 0.00). However, the highest double fruit production of 'Somerset' was observed in 2007 (41.85 ± 12.77).

The cultivars that consistently produced lower amount of double fruits were 'Marvin' and 'New Star' (Fig. 4). Thus, our results seem to indicate that double fruit production has a strong genetic influence, accordingly with Roversi *et al.* (2008).

Caprio and Quamme (2006) found that rainfall during fruit development and harvest of sweet cherry reduced production because of rain-induced cracking. However, no cracking sensitivity was observed in the studied sweet cherry cultivars under our climatic conditions, probably due to scarce rainfall during maturity fruit period.

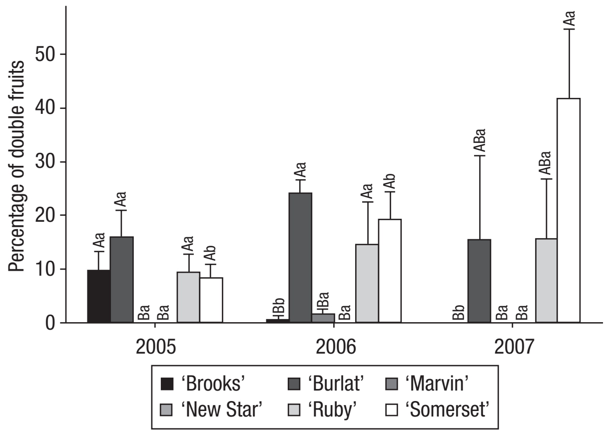


**Figure 4.** Percentages of double fruits observed in six sweet cherry cultivars calculated at Jumilla (Murcia) from 2005 to 2007. Different capital letters represent differences between cultivars for the same year and lower-case letters represent differences between years within the same cultivar at 0.05 probability level (LSD test).

## Fruit quality atributes

It is known that environmental factors and orchard management (choice of rootstock, pruning, fertilisation and irrigation) affect cherry fruit quality, in terms of different concentration of nutritive and bioactive compounds (Predieri *et al*., 2004; Gonçalves *et al*., 2006). However, in this work all cherry cultivars were in very close farms, under similar cultural practices. Trees were of the same age and grafted onto the same rootstock. Therefore, differences in quality attributes between cultivars that will be commented below should be attributed to genetic characteristics of each cultivar.

Fruit weight was very different between cultivars and stages (Table 3). 'New Star' showed the largest fruit in all stages, whereas 'Cristobalina' had the smallest fruits (Fig. 5). At the commercial stage (S4) the values

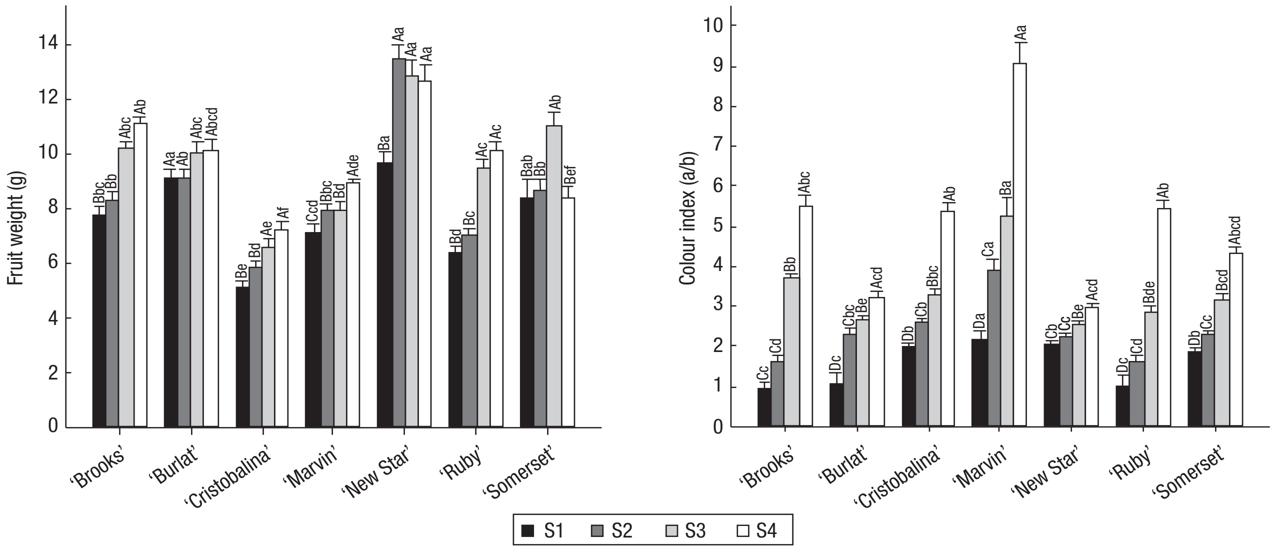


**Figure 5.** Fruit weight and colour index (a/b) evolution from S1 to S4 in seven sweet cherry cultivars. Data are average ± SE. Different capital letters represent differences between stages for the same cultivar and lower-case letters represent differences between cultivars within the same stage at 0.05 probability level (LSD test).

were 12.70 ± 0.54 g for 'New Star' and 7.26 ± 0.30 g for 'Cristobalina'.

In sweet cherry, the ripening process is characterized by colour changes, from green to red, which can be followed by the evolution of L*, a* and b* parameters and the colour indices Chroma and Hue. The colour index (a*/b*) has been proposed as a good colour index for sweet cherry cultivars (Díaz-Mula *et al.*, 2009), since it shows a continuous increase during fruit ripening on the tree and has been used in other species such as apple, pear and peach. In accordance our results show an increase from S1 to S4 in all the studied cultivars in this paper (Fig. 5), although important differences were found between them (Table 3). Thus, the highest value at S4 stage was found for 'Marvin' (4.31 ± 0.18) and the lowest for 'New Star' (2.95 ± 0.13), showing the darkest red and the lightest red colour, respectively. Moreover, taking into account the relationship between a*/b* index and total anthocyanin concentration in sweet cherry cultivars (Díaz-Mula *et al.*, 2009), great variations between cultivars would exist in anthocyanin concentration leading to differences in antioxidant activity and health beneficial effects (Scalbert *et al.*, 2005; Díaz-Mula *et al.*, 2009; Serrano *et al.*, 2009).

Total soluble solids increased from S1 to S4 in all sweet cherry cultivars, with values at S4 ranging from ≈12 °Brix in 'Burlat' to ≈20.5 °Brix in the cultivars 'Brooks' and 'Ruby' (Fig. 6). In general, these cultivars have high content of total soluble solids, since in other sweet cherry cultivars, harvested at commercial ripening stage, values between 11 and 25 °Brix have been reported (Girard and Koop, 1998; Esti *et al.*, 2002; Serrano *et al.*, 2005a,b). The main sugars found in cherry cultivars have been glucose and fructose, followed by sorbitol and sucrose (Girard and Koop, 1998; Serrano *et al.*, 2005a; Usenik *et al.*, 2008). Important differences were also found in total acidity among sweet cherry cultivars (Table 3). Thus, the highest values were found in 'Somerset' (≈1.6 g 100 $g^{-1}$) followed by 'New Star' (≈1.3 g 100 $g^{-1}$) and the remaining cultivars showed values of 0.6-0.7 g 100 $g^{-1}$ (Fig. 6). However, in stone fruits other than cherries, such as nectarines (Iglesias and Echevarría, 2009) and peach (Byrne *et al.*, 1991) acidity decreased over the development and ripening, while an accumulation was observed but not in all cultivar tested, in agreement with the reported increase in total acidity as harvesting date was delayed in 'Lapins' and '4-70', also called 'Marvin', cherries (Drake and Elfving, 2002; Serrano *et al.*, 2005a). Nevertheless, for sweet cherry the ratio soluble

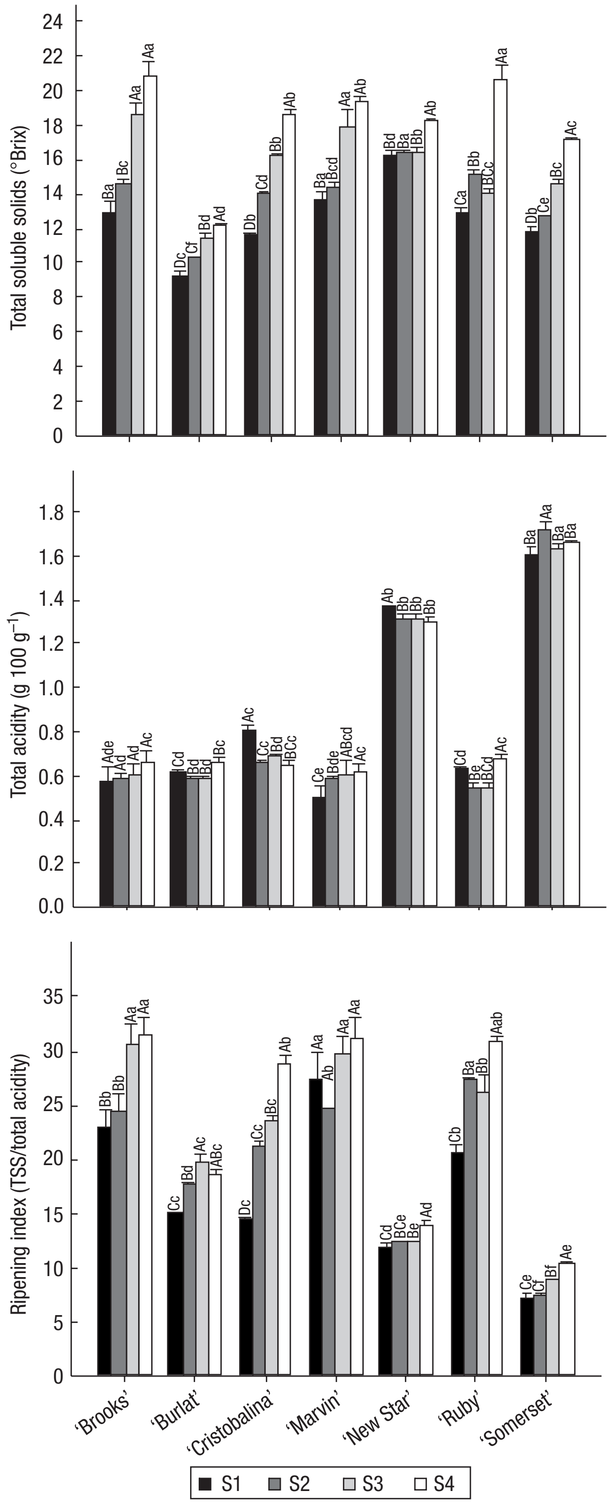


**Figure 6.** Total soluble solids, total acidity and ripening index evolution from S1 to S4 in seven sweet cherry cultivars. Data are average ± SE. Different capital letters represent differences between stages for the same cultivar and lower-case letters represent differences between cultivars within the same stage at 0.05 probability level (LSD test).

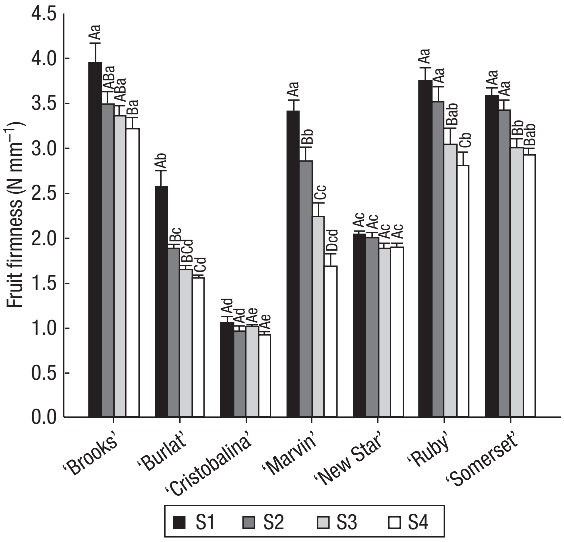


**Figure 7.** Fruit firmness evolution from S1 to S4 in seven sweet cherry cultivars. Data are average ± SE. Different capital letters represent differences between stages for the same cultivar and lower-case letters represent differences between cultivars within the same stage at 0.05 probability level (LSD test).

solids/total acidity has been proposed as determining consumer acceptance (Crisosto *et al.*, 2003). This ratio increased along the ripening process on tree (from S1 to S4) in all sweet cherry cultivars, with the highest values being reached in 'Brooks', 'Marvin' and 'Ruby' cultivars and the lowest in 'New Star' and 'Somerset' (Fig. 6).

Fruit firmness is also an attribute very appreciated by consumers although there are considerable genotypic differences (Table 3), as can be observed in Figure 7, with firmness levels at S4 ranging from ≈1 N $mm^{-1}$ in 'Cristobalina' to ≈3.20 N $mm^{-1}$ in 'Brooks'. Softening in the last days of ripening of sweet cherry has been attributed to increases in ß-galactosidase activity, unlike in most of fruits, in which softening is dependent on pectin depolymerization due to polygalacturonase activity (Batisse *et al.*, 1996; Gerardi *et al.*, 2001).

As final conclusions, the knowledge of floral biology, fruit set behaviour and fruit quality of the cultivars studied here could be useful to choose the appropriate ones to be grown under Mediterranean climatic conditions or used as parentals in future breeding programs. In this sense, 'Cristobalina' had high fruit set percentages although fruit size and firmness values were very low, while 'New Star' was the best cultivar in terms of consistent high fruit set percentages and low percentage of double fruits as well as high quality attributes such as good fruit size, dark red colour and firmness levels.

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