Productivity, chemical composition and sensory quality of “Martainha” chestnut variety treated with Silicon

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ABSTRACT

The increasing demand for healthy products rises the pressure on the chestnut production due to their nutritional qualities and beneficial health effects. Martainha chestnut variety is most well-adapted with great economic importance due to its precocity and technological properties. The exogenous application of Silicon has an important role in agriculture because of improvement of plants nutrition. Nevertheless, the knowledge of impact of Silicon application in the production, sensory quality and chemical composition of chestnut fruits is limited. The application of Si in leaves (SL) and soil (SS) have important action on the prophylactic properties and the promotion of chestnuts health. Moreover, higher number of healthy fruits, caliber, fruits without rotten and tortrix infection and lower water loss in post-harvest chestnuts, in SL and SS samples, highlights the Si positive action. Additionally this study emphasizes some positive effects of Silicon on the chemical and sensory profile.

1. Introduction

Chestnut (Castanea sativa Mill.) has followed the man since the Paleolithic age (Carvalho & Rodrigues, 2016) and is one of the oldest edible fruits in Portugal. One of the main production areas is located in Sernancelhe region (North-central of Portugal) with an important role in the economy and landscape patrimony, contributing to around 1 000 tons of total chestnut Portuguese’s production (26,780 tons) (INE, 2016) In order to preserve the biological material and to improve its cultivation, the Protected Designation of Origin (PDO) “Castanha dos Soutos da Lapa” was created in 1994. In this PDO environmental conditions, Martainha chestnut variety is most well-adapted with great economic importance due to its precocity.

The market has been showing an improved interest in this fruit due to their nutritional qualities and potential beneficial health effects. Indeed, chestnuts are rich in carbohydrates and are a good source of essential fatty acids and minerals (Borges, Gonçalves, Carvalho, Correia, & Silva, 2008). Moreover, chestnut fruits present several vitamins, such as C, E, thiamine, riboflavin, niacin, pyridoxine and folate (De Vasconcelos, Bennett, Rosa, & Ferreira-Cardoso, 2010) and are gluten free (Aguilar, Albanell, Miñarro, & Capellas, 2016).

Silicon (Si) plays an important role in plant-environment relationships, increasing the quality and quantity of crops production (Jayawardana, Weerahewa, & Saparamadu, 2014). Numerous studies have confirmed that plants Si fertilization improves their resistance to diseases and pests (Epstein, 2009) to salt stress (Liank, Sun, Zhu, & Christie, 2006) and water stress (Sacala, 2009). Water stress is of extreme importance since chestnuts are a perishable fruit, which preserves commercial quality and turidity for a post-harvest small time. The preservation of the water content inside chestnuts for a longer period prevents the fruits from drying out.
quickly and acquiring a darker color. So, avoid chestnuts water losses allows the preservation of their nutritional and sensory properties in terms of appearance and taste (Ertan, Erdal, Alkan, & Algul, 2015).

The current intensive use of soils and the systematic application of chemical fertilizers has led to the depletion of the amount of Si available in the soils, with the consequent loss of crops yield (Lavinsky, 2013) Si deficiency also reduces pollen fertility, which affects fruit yield and quality, compromising its commercial value (Jarosz, 2014). Chestnut, like as other cultures, exposed to several biotic and abiotic stresses, also presents limitations in the production and vigor of the trees (Zhang et al., 2013).

Since information about the effect of Si application in the production, sensory characteristics, water loss and chemical composition of chestnut fruits is limited, the aim of this study is to evaluate the effect of Si-fertilization on Martainha chestnut’s sensory properties, proximate composition, fruit production and general quality of chestnuts, by application of Si in soil and leaves.

2. Material and methods

2.1. Study site and plant selection

The experiment was carried out in a chestnut orchard (Martainha variety), about 16 years of age, located in Sernancelhe – Portugal (N 40° 53’ 55.81”, W 7° 29’ 38.58”), and was arranged in a completely random design with 12 chestnut trees, 4 per treatment, dispersed in the orchard in a good sanitary and nutritive status.

2.2. Silicon treatments

Three treatments were carried out: C – trees didn’t receive any potassium silicate (SiK®); SS and SL – 15 L of SiK® at 10 mM SiK® concentration was respectively applied: to the soil or sprayed directly to the leaves. The SiK® solution was prepared in the laboratory according to Carneiro-Carvalho et al. (2017) and after was adjusted the solution to pH 6.9 using 30 M hydrochloric acid (HCl). The SiK® concentration used was the one that presented the best results in previous studies (Carneiro-Carvalho et al., 2017).

2.3. Samplings of leaves, fruits, outer skins and Si content essays

From each treatment, 40 leaves completely developed were sampled from the whole tree canopy were sampled and used to determine their Si content. Samples were collected in a brown paper bag, in an oven with forced air circulation at 70°C, and left to complete dehydration (until reached constant mass). For Si content in fruits was used 32 healthy chestnuts per treatment (8 chestnuts per tree). The fruits were hand peeled and freeze-dried in a Dura Dry µP from F.T.S. Systems (Stone Ridge, New York) for 48 h, and powdered using a model 843 food processor (Moulinex, Italy) (De Vasconcelos, Bennett, Rosa, & Ferreira-Cardoso, 2007). For the Si content determination in both inner (episperm) and outer chestnut-skins (pericarp), were used 120 fruits peels per treatment (30 chestnuts peels per tree) that were randomly sampled. The determination of Si content in leaves, fruit and skins (inner and outer chestnut-skins) was performed by adding 0.1 g of dry samples to 2 mL of hydrogen peroxide (H₂O₂) and 3 mL of sodium hydroxide (NaOH) (Komdärfer, Pereira, & Nolla, 2004). Their Si content were read at 410 nm and the values were expressed in g kg⁻¹ of dry mass.

2.4. Chestnut’s fruits, Silicon effects on:

2.4.1. Physical characteristics

Concerning physical parameters determination of chestnuts, 120 burs were randomly collected directly from each treatment (30 per chestnut tree), on the third week of October, according to the tree phenological cycle. In the laboratory, for each tree from each treatment, the number of well formed, aborted, rotten and with tortrix infestation fruits was determined. To the caliber determination (fruits kg⁻¹) only were considered the well-formed fruits which were randomly collected. In the total number of fruits was been included: aborted and well-formed chestnuts. Subsequently, the well-formed chestnuts were divided into rotten, with tortrix infestation and healthy fruits (Dinis, Ferreira-Cardoso, Peixoto, Costa, & Gomes-Laranjo, 2011).

2.4.2. Pollination

It was also intended to evaluate if Si-fertilization induced differences in the efficiency of free pollination. Thus, the efficiency of free pollination was determined according to López (2013) and by the Equation (1):

\[ E = \frac{100 \times n}{N} \]

Where, N represents the number of burs; n, the number of well-formed chestnuts; and E, the pollination efficiency. The results are related to 4 trees for each treatment.

2.4.3. Water loss

For water loss evaluation the procedure of Nunes and Emond (2007) was adapted. Forty chestnuts fruits per treatment (10 per tree) were randomly collected and placed at room temperature (25°C). Afterward, the weight was evaluated in an analytic balance, until the chestnuts’ weight remained constant, every 24 hours in the first 3 days post-harvest, and then, in the remaining days, every 48 hours. The percentage of water loss was obtained by calculating the variation of the weight over time.

2.4.4. Proximate composition

The proximate composition of chestnuts fruits – DM (dry matter), CF (crude fat), CP (crude protein), Sug. S (soluble sugars), ST (starch) and AE (ashes) – was done according to the methodologies described in Table 1. The analytical procedures were carried out with the same chestnut flour prepared for Si content determination.

2.4.5. Sensory profile

Twenty chestnuts, randomly collected from each treatment and stored in perforated plastic bags in the refrigerator, were used for sensory analysis. The tests ran in a room with controlled environment and material needed for each task, according to ISO 8589 (ISO 8589, 2007). The chestnuts, after being washed 3 times in tap water, were cut and boiled in water with 2 g of salt, for 30 min. After cooling to room temperature (18 ± 2°C), the chestnut samples in white Pyrex dishes appropriately coded were evaluated by a panel of 12
tasters from ECVA/DeBA-UTAD, trained and experienced in sensory analysis. Mineral water and toasted breed were given between samples evaluations for cleansing the palate. A quantitative descriptive analysis (QDA) was carried out, using proof sheets with descriptors adapted from Warmund (2015). In Table 4 are present the sensory attributes (descriptors), its description, as well as the intensity scale that tasters used to quantify the sensory attributes a structured scale from 1 (less intense) to 5 (more intense) points, according to the reference ISO 4121 (ISO 4121, 2003).

In Table 2 are present the material used on the determinations of the different methods, the number of leaves, fruits, burs and the number of replications per each treatment, this table was performed to aid in the understanding of the material and methods.

### 2.5. Statistical analysis

Data were submitted to the analysis of variance (ANOVA) and means were compared using Duncan’s multiple range test at 5% of significance level (p < 0.05). The analysis of the sensorial profile was done through the spider graphic in Excel. The results represented in the Tables and Figures are means ± SE of four replicates of each treatment. Also, a Principal Components Analysis based on a correlation matrix (Corr-PCA) was performed for all the parameters analyzed. For these adopted statistical analyses were used the Statview and STATISTICA 2010 software.

### 3. Results

#### 3.1. Si content in leaves, fruits and skins

Si content in chestnut leaves, skins and fruits on C, SL and SS treatments is shown in Figure 1. It was in the leaves, for all treatments, that the highest Si content was recorded, as opposed to the smaller amount observed in the fruits. Both skins and fruits had the largest and significant amount of Si in SS, in opposition of the leaves where the highest concentration of Si was registered in SL, 1.86 mg kg⁻¹, which is compatible with Si application.

Concerning to the increases of Si registered in all the structures where it was applied, compared to the content obtained in the C, the concentration of this mineral registered in both skins and fruits was significant. In fact, when compared to the untreated chestnuts, the increase of Si in the skins on SS and SL was 6.5- and 4.1-fold greater, respectively. The increase of Si on the fruits was smaller but still significant, i.e. 2- to 3-fold greater in SL and SS, respectively. However, it was in the leaves that the increase of Si was greater, 5.8 (SL) and 4.3 (SS).

### Table 2. The type and number of replications was carried out to comment the results.

| Determination of | Material                  | C   | SL | SS   |
|------------------|---------------------------|-----|----|------|
| Si present in leaves | leaves                    | 4*  | 4* | 4*   |
| Si content in fruits | fruits (chestnut flour)   | 32  | 32 | 32   |
| Si content in skins | skins                     | 120 | 120| 120  |
| Physical characteristics determination | burs and fruits | 120 | 120| 120  |
| Effects on pollination | burs and fruits | 120 | 120| 120  |
| Effects on water loss | fruits                  | 40  | 40 | 40   |
| Proximate composition | fruits (chestnut flour)  | 32  | 32 | 32   |
| Sensory profile    | fruits                    | 20  | 20 | 20   |

* Three replications for each treatment.
* In the physical characters determination were used the 120 burs per treatment to obtain the chestnuts fruits which were counted and presented in the Table 3 the average values for each treatment.
* En la determinación de los caracteres físicos se utilizaron 120 erizos por tratamiento para obtener los frutos de castaños, contados y presentados en la Tabla 3 con los valores promedio para cada tratamiento.
3.2. Chestnut’s physical characteristics and fruit setting

Table 3 shows the average values of Si application effect in the productivity, in the physical or biometric characteristics of chestnut fruits, and fruit setting. Significant differences between all treatments for all parameters analyzed were observed. The SL showed the highest number of chestnuts fruits, the highest number of well-formed and healthy fruits. On the other hand, it was in SS that the lowest number of aborted and rotten fruits were recorded. The C had the worst results because presented the lowest total number of fruits, the lower number of the well-formed fruits and healthy fruits, and the highest number of aborted, rotten and tortrix infected fruits. The best caliber was registered in the SS with 61 fruits kg\(^{-1}\). No significant differences were observed between the C and SL for this parameter. However, it was the C that showed the smallest chestnuts fruits. Significant differences were detected for aborted fruits comparing C with SS and SL, but not between SS and SL. The same result is for rotten fruits. The effect of the Si on the fruit setting was considerably smaller for SS than SL. Indeed, it was in the SL that the highest fruit setting was recorded, as opposed to the C with the lowest value.

3.3. Chestnut’s water loss

In the Figure 2 can be observed the weight loss of the chestnut fruits occurred during storage in all treatments. At the end of the 16th day, significant differences between the C and both SL and SS treatments was observed. The C samples showed the greatest loss of water (62%), while it was in the soil- and foliar- applied Si treatments where the chestnuts lost less water. No significant differences in water loss were observed among the chestnuts treated with Si. However, from the 8th day, it was observed a 5% decrease in water loss in SL when compared with SS.

3.4. Chestnut’s proximate composition

Table 3 shows the proximate composition of chestnuts fruits. As can be observed, the foliar and soil Si application influenced some parameters of the basic chemical composition.

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Table 3. Means and respective standard errors of the biometry and proximate composition of the chestnuts fruits from the control (C) and Si application on leaves (SL) and soil (SS). In the total number of fruits was included: aborted and well-formed chestnuts. Subsequently, the well-formed chestnuts were divided into rotten, with tortrix infestation and healthy fruits. Values were means ± standard deviation (SD). Values within each column with different letters on each row are significantly different, according to the Duncan’s multiple range test.

| Parameters (fruits) number                                      | Treatments | ANOVA |
|-----------------------------------------------------------------|------------|-------|
|                                                                 | C          | SL    | SS    | p-value |
| Total                                                           | 89.0 ± 1.9 | 101.3 ± 2.5 | 90.8 ± 4.3 | 0.045   |
| Aborted                                                         | 54.5 ± 1.9 | 43.3 ± 2.4 | 41.3 ± 3.8 | 0.040   |
| Well-formed                                                     | 34.5 ± 3.1 | 58.0 ± 4.1 | 49.5 ± 1.5 | 0.000   |
| Rotten                                                          | 1.75 ± 0.48| 0.75 ± 0.48 | 0.50 ± 0.30 | 0.007   |
| Tortrix infestation - Well-formed                               | 3.25 ± 0.25| 2.50 ± 0.29 | 2.50 ± 0.29 | 0.004   |
| Healthy                                                         | 29.5 ± 2.5 | 54.8 ± 3.9 | 46.5 ± 1.5 | 0.000   |
| Caliber (fruits kg\(^{-1}\))                                    | 69.5 ± 2.9 | 67.0 ± 3.2 | 61.0 ± 4.0 | 0.005   |
| Fruit setting                                                   | 115.0 ± 5.6| 193.3 ± 6.1 | 158.3 ± 3.6 | 0.000   |
| Parameters (g 100g\(^{-1}\) DM)                                |            |       |       |     |
| Dry matter (DM) (g 100g\(^{-1}\) FW)                           | 43.5 ± 0.41| 49.6 ± 0.29 | 48.5 ± 0.35 | 0.000   |
| Crude fat (CF)                                                  | 0.71 ± 0.06| 0.97 ± 0.04 | 1.01 ± 0.02 | 0.001   |
| Crude protein (CP)                                              | 5.40 ± 0.31| 6.34 ± 0.06 | 6.21 ± 0.04 | 0.000   |
| Soluble sugars (Sug. S)                                         | 11.5 ± 0.71| 12.5 ± 0.90 | 11.0 ± 0.83 | 0.436   |
| Starch (ST)                                                     | 55.4 ± 0.34| 60.9 ± 0.68 | 62.3 ± 0.45 | 0.000   |
| Ashes (AE)                                                      | 2.59 ± 0.06| 2.68 ± 0.14 | 2.71 ± 0.09 | 0.406   |

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Figure 1. Means and respective standard errors of the Si content in leaves, skins and fruits for each treatment- control (C) and Si application on soil (SS) and on leaves (SL). In each sample, bars/treatments have different letter, so are significantly different (p < 0.05), according to Duncan’s multiple range test.

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Figure 1. Medias y errores estándar respectivos del contenido de Si en hojas, piel y frutos para cada tratamiento-control (C) y aplicación de Si en el suelo (SS) y en las hojas (SL). En cada muestra, las barras/tratamientos tienen una letra diferente, por lo que son significativamente diferentes (p < 0.05), conforme a la prueba de rango múltiple de Duncan.
Indeed, there were significant differences amongst the control and soil- and foliar-applied Si treatments for the DM, CF, CP and ST contents.

Concerning DM content, the highest values were found in SL and SS (49.6 and 48.5 g 100g$^{-1}$ FW, respectively), against 43.5 g 100g$^{-1}$ FW for C. The same observations were made for the contents of CF, CP and ST, where the C had shown the smaller level in these constituents. The content of AE was tended to be lower in C, although there were no significant differences between the three treatments.

When the DM content was compared with the caliber and loss of water, the results are in accordance, since the chestnuts of the treatment with the best caliber, SS, were also the ones that lost less water and had a high DM content. On the other hand, the C is that had the lower DM content, and presented worse caliber and the highest water loss.

### 3.5. Chestnut’s sensory profile

The sensory profile of each chestnut sample is shown graphically in Figure 3. It is possible to verify that the different treatments (C, SL, and SS) are very similar. However, in what concerns the attributes "peelability" (easy of peeling the inner and outer skins), "characteristic odor", "initial firmness" and "dissolvability", there are slight differences between the samples, especially on "peelability" and "initial firmness" for the SL and the "characteristic odor" and "dissolvability" relatively to the SS. Still, the results of the ANOVA and the Duncan’s multiple range test, presented in Table 4, show slight differences between the treatments.

| Attributes          | Description                                                                 | Treatments |
|---------------------|-----------------------------------------------------------------------------|------------|
| Peelability         | Ease of peeling the episperm and perisperm                                 | C  SL      |
| Characteristic odor | Characteristic odor of cooked chestnuts                                     | 2.9 ± 1.2  |
| Initial firmness    | Necessary force to initially bite the chestnut using the incisors          | 3.2 ± 1.4  |
| Dissolvability      | Degree to which the sample dissolves or remains semisolidd when manipulated | 3.3 ± 1.3  |
| Sweet taste         | Basic taste associated with sucrose                                         | 3.5 ± 0.9  |
| Sour taste          | Basic taste associated with citric acid                                     | 3.1 ± 0.0  |
| Bitter taste        | Basic taste associated with caffeine                                        | 3.1 ± 0.0  |
| Astringency         | Sensation of drying on the mouth surfaces                                  | 3.1 ± 0.8  |
| Chestnut flavor     | Intensity of all chestnut characteristics including sweet, oily, slightly   | 3.8 ± 0.8  |
|                     | mustard and/or butter, earthy, woody, astringent and bitter flavors         | 3.8 ± 0.8  |
| Hazelnut flavor     | Sweet, oil somewhat woody aromatic associated with hazelnuts                | 1.3 ± 0.5  |
| Almond flavor       | Sweet cherry pit-like nutty aromatic associated with almonds                | 1.4 ± 0.7  |
| Butter flavor       | Aromatics commonly associated with natural, slightly salted butter          | 1.7 ± 0.7  |
| Caramel flavor      | Aromatics associated with caramel                                           | 1.6 ± 0.6  |
| Yeast flavor        | Aromatics, sweets, fermented fruits, vegetables, grains or with yeasty notes| 1.2 ± 0.4  |
| Mustard flavor      | Sweet, woody sour, vinegar-like, somewhat pungent, slightly horseradish-like| 1.0 ± 0.0  |
|                     | aromatics associated with prepared mustard                                 |            |
| Floral/fruity flavor| Aromatics associated with non-citrus fruits and flowers                    | 1.4 ± 0.7  |
| Musty/earthy flavor | Aromatics of a damp basement or soil or decaying vegetation                 | 1.2 ± 0.4  |

*The attribute is not perceived: 1; doubts in the perception of the attribute: 2; the attribute is perceived, but moderately: 3; the attribute is perceived: 4; the attribute is perceived and its intensity is maximal: 5.

*El atributo no se percibe: 1; Dudas en la percepción del atributo: 2; El atributo se percibe, pero moderadamente: 3; El atributo se percibe: 4; El atributo se percibe y su intensidad es máxima: 5.
that these differences are only significant for the peelability attribute, being the C chestnuts more difficult to peel.

### 3.6. Corr-PCA of all the parameter analyzed

Correlation among Si content in leaves, fruits and skins, chestnuts water loss, fruit setting, physical, chemical and sensory data was studied performing a Corr-PCA (Figure 3), resulting in that the three treatments were disposed in different quadrants of the graphic. The PC1 explained 60.45% of the total variance, while the PC2 explained 39.54%. Both PC1 and PC2 explained 99.99% of the total variance.

The C samples are in the upper right quadrant of the PCA projection and they are characterized by the variables “aborted fruits”, “rotten fruits”, “tortrix infestation fruits”, “CF” and the sensory descriptors “hazelnut flavor” and “almond flavor”.

The chestnuts from SL are in the upper left quadrant of the PCA and stands out for its higher content of some chemical/physiological parameters: “Si leaves”, ‘Well-formed fruits’, ‘Healthy fruits’, ‘Fruit setting’, and the sensory parameters “Peelability”, ‘Initial firmness’ and “Fermented flavor”. The chestnuts from SS are in the lower left quadrant of the PCA, which is characterized by the variables: “Si skins”, ‘Si fruits’, ‘Water loss’, “AE”, “DM”, “CP”, “ST”, and the sensory descriptors “Bitter taste” and ‘Sour taste’.

### 4. Discussion

The results of Si content in leaves, fruits and skins were in agreement with Haynes (2017) findings since the highest concentration of Si in the fruits and skins was recorded in the SS treatment.

The plants have the capacity to absorb and translocate Si from the roots to the shoots where it is deposited, mainly in the form of phytolith silica, in the leaf cells (McCarthy & Meredith, 1988). The phytoliths action in plants is diverse and multi-functional when the plants undergo biotic and abiotic stress (Epstein, 2009; Jarosz, 2013) and its action have been frequently demonstrated in diverse crops (Haynes, 2017; Marodin et al., 2014). In the present study,
the caliber, the higher number of healthy fruits, without rotten and tortrix infection, in the SL and SS treatments, suggest the increase of plant resistance to abiotic and biotic stress, resulted from exogenous Si application. Indeed, the Si in fruit skins increases the fruit firmness and cuticle thickness by the deposition of Si phytoliths in the cell walls, acting as a mechanical barrier (Weerahewa & David, 2015) and improves the levels of phenol compounds, important in the defense against pests and diseases (Mditshwa, Bower, Bertling, Mathaba, & TesLay, 2013; Torlon, Heckman, Simon, & Wyenandt, 2016).

On the other hand, previous studies have shown that the increase in the productivity by Si fertilization could be explained by a better flowering, a higher fertility of the pollen and consequently a better fruit set promote (Jarosz, 2014).

In a chestnut orchard, one variety is well pollinated if the fruit setting value is between 165 and 225 (Breisch, 1995) or higher than 150 (López, 2013). The present results highlight the effect of Si when applied to the soil (fruit setting = 193.3). The C and SL treatments revealed low fruit setting when compared to the Spanish varieties whose values varied between 192 and 244 (López, 2013).

In addition, it was observed the importance of this mineral to meet the desired final product with direct repercussions on the conservation postharvest and their economic valuation. Loss of substantial amounts of water may result in worse quality and economic losses, and even when weight losses are subtle, the visual aspect, composition and eating quality of the product may be impaired (Nunes & Emond, 2007). Also chestnuts with calibers between 60 to 90 fruits kg⁻¹ can be more expensive (Martins et al., 2011) about twenty cents per euro, than calibers above these values.

The values of DM, ST and CP content founded in this study are in accordance with the previously reported by several authors (Borges et al., 2008; De Vasconcelos et al., 2010; Dinis et al., 2011; Pereira-Lorenzo, Ramos-Cabrera, Diaz-Hernández, Ciordia-Ara, & Rios-Mesa, 2006). Indeed, De Vasconcelos et al. (2010) pointed to DM content of Martainha between 40.3 and 50.1 g 100 g⁻¹ FW, and more recently Silva et al. (2016) founded values of DM in this variety between 46 and 48 g 100 g⁻¹ FW. The C sample showed moisture content (Table 3) outside the limits announced by Silva et al. (2016) which may denote the effect of the application of Si in this parameter. On the other hand, previous study showed that Martainha presented 3.89 g 100 g⁻¹ DM of CP (De Vasconcelos et al., 2007) while the current analysis founded that all three treatments had higher contents (Table 3), being in agreement with the values (4.5 to 9.6 g 100 g⁻¹ DM) (Pereira-Lorenzo et al., 2006). However, our results showed that the Si application in the leaves or in the soil does not interfere with the CP content in the chestnut kernels. The values for ST content previously reported for chestnut kernels were between 42.2 and 66.6 g 100 g⁻¹ DM (De Vasconcelos et al., 2010; Dinis et al., 2011; Pereira-Lorenzo et al., 2006). Our results are within this range of values and close to the value for Martainha variety (63 g 100 g⁻¹ DM) (Silva et al., 2016). The present results revealed that all three treatments had low CF content (Table 3) even compared to those of De Vasconcelos et al. (2010) in the same variety (1.9 g 100 g⁻¹ DM). Also, our results suggest that the Si application in the leaves or in the soil does not interfere with the Sug. S and AE contents, since no significant differences were found among treatments. Even so, the AE content is higher than that found by other authors (Borges et al., 2008; Pereira-Lorenzo et al., 2006) 1.87 and 2.3 g 100 g⁻¹ DM, respectively.

Sensorial analysis showed a significant effect of the Si application on “peelability”, “initial firmness”, “characteristic odor” and “dissolvability”. The multivariate analysis indicated that “peelability” on chestnuts from SL and SS was the sensory characteristic that is significantly different from C. Other interesting studies has been referred to the application of Si and the quality of fruits. For example, Si application in strawberry plants increase the sugar content and improve the palatability of this fruits, namely in terms of flavor and aroma, compared to fruits from Si-free plants (Silva, Resende, & Trevizan, 2013). The overall results of the Corr-PCA revealed closer proximity of the chestnuts from SL and SS mainly due to the “well-formed fruits number”, “healthy fruits number”, “peelability”, “water loss”, and “CP” and “ST” content. This is an outstanding result, useful for nutritionists, consumers and growers because if on one hand, these fruits have better nutraceuticals characteristics (Cruz, Abraão, Lemos, & Nunes, 2013; De Vasconcelos et al., 2010) on the other hand, the productivity is higher, and thus greater economic yield for producers (Martins et al., 2011). In addition, the industry looks for kernels with no presence of cracks, good caliber, optimal storage capacity, and good sanitary aspect after storage (López, Torrado, Fuciños, Guerra, & Pastrana, 2004) responding the SL and SS chestnuts to these requests.

Moreover, data from caliber, tortrix infestation, rotten and aborted fruits were better compared with the control, which once again highlights the positive action of Si on the characteristics of chestnut fruits.

The fertilization treatments with Silicon are advisable in presence of soils with reduced availability of this element that is normally present in the soils.

5. Conclusion

This study points out important results for the chestnut crop. The application of Si in both leaves and soil revealed to have an important action on the prophylactic properties and the promotion of chestnuts health. Overall results show the Si positive action in the higher number of healthy fruits, better caliber, fruits without rotten and tortrix infection and lower water loss in post-harvest chestnuts, in both SL and SS treated samples, by the deposition of Si phytoliths in the cell walls, acting as a mechanical barrier. In addition, the positive effect of Si on the fruit size was clear, and also the proximate analysis allows us to state that Si affects positively the chemical composition of the chestnut fruits.

Regardless of the small significant differences between Si treatments, the overall results of fruits’ total number, healthy fruits, fruit setting, initial firmness, and peelability of the chestnuts obtained from the SL, suggest that this type of treatment suits perfectly to achieve high chestnut’s yields and quality.

Disclosure statement

No potential conflict of interest was reported by the authors.
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