International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 29 No. 1 October 2021, pp.30-36

Effects of Foliar Calcium Applications on Raspberry Fruit Quality and Shelf Life

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***Abstract*—The current study investigates the effect of foliar calcium applications on fruit quality of 'Carmina' raspberry. The first product is a liquid fertilizer (CaO: 12%) applied in three doses: T1 (100 cc/hl), T2 (200 cc/hl) and T3 (400 cc/hl). The second product is Calcium Nitrate (CaO: 26.3%) used in a single dose T4 (230.8 g/hl). Data collected included fruit weight and caliber, rating of fruit colour, firmness, acidity, total soluble solids (TSS), and fruit weight loss during storage. Fruit and leaves were sampled to determine Ca concentration. Results show that foliar treatments had no significant effect on fruits average weight, nor their size. Treatments T2 and T3 significantly increased fruit firmness. Fruit TSS and acidity showed no significant differences from T0. Applications did not affect post-harvest fruit weight losses. Foliar application of calcium caused an increase in leaf calcium content of 46 and 42% respectively for T2 and T3, and an increase in fruit calcium content of 35 and 18% respectively for T2 and T3 compared to T0. There was no difference between the contents of leaves and fruits regarding the other elements (Mg, K, Fe, Mn, Zn and Cu). The right frequency of application is once every 8 days.**

Keywords—Calcium; foliar fertilization; raspberry (Rubus idaeus); fruit firmness; post-harvest quality

I. INTRODUCTION

In the last decade, the berries sector and in particular raspberries are booming with world production reaching 822,493 tonnes in 2019. Morocco's production in the same period was around 24,500 tons [1].

In recent years, the raspberry tree has become increasingly important because of the possibilities of extending its cultivation in areas with mild winters, such as the countries of the Mediterranean basin. The areas dedicated to raspberries in Morocco went from 30 ha in 2006 to 3,100 ha in 2019-2020 and exports reached 35,400 tonnes in the same campaign [2]. The country has methodically invested in consolidating its reputation in many importing countries as a reliable supplier of high-quality fruits and vegetables. Nowadays, raspberries culture occupies a modest place in three of the most important regions in Morocco, namely Loukkos, Gharb and Souss-Massa. It plays a substantial role in the socio-economic development of these regions as it is considered a highly profitable and employment-generating culture.

However, raspberries are very perishable fruits with high respiration rates and a fragile structure. They are easily spoiled by mold and have a very short shelf life of around 3 to 5 days [3]. This is particularly problematic for export, with a considerable loss of firmness and freshness and the rapid development of rots.

In general, a nutrient-balanced fertilization is essential to ensure optimal yield and to have good quality fruit [4]. Calcium is one

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of the mineral elements essential for the growth of a plant. Along with nitrogen and potassium, it is one of the elements with the highest levels in plant tissues [5]. Calcium plays its main role outside of cells. One of the primary functions of calcium is to form bonds between the walls of cells. It therefore maintains the structure between cells by cementing them to each other. Through its structural role, calcium helps maintain the quality of flowers, fruits and vegetables after harvest and during storage [6].

However, the absorption of calcium is described as passive, since its entry into the plant is mainly related to the absorption of water by the roots. Inside the plant, calcium must be transported to the leaves and fruits. To do this, it moves through the xylem. Young leaves and fruits are more susceptible to calcium deficiency: These organs, by sweating little, receive less water and calcium. Calcium being non-mobile, once localized and fixed in the older tissues, it cannot be redistributed to young leaves and fruits. Thence, it is necessary to have a constant supply of calcium to continue growing [6]. Therefore, the main problem is determining the right amount of calcium to get the desired effect on the fruit. Treatment of the soil with calcium to increase the fruit's calcium concentration had limited effects while direct application of calcium to fruit is the most effective method of increasing the level of calcium in fruit [7]. In the current study, the effects of foliar applications based on calcium on the quality and shelf life of fruits of "Carmina" raspberry (*Rubus idaeus*) were investigated.

II. Materials And Methods

The present study was conducted under a greenhouse located in the province of Chtouka-Aït Baha, 40 km south of Agadir, Morocco (30.107130, -9.472122). The region is characterized by a semi-arid climate. The average temperature varies moderately, it is around 22°C. Precipitation is generally low and irregular, rarely exceeding 250 mm. The soil at the experimental site is sandy.

All the treatments were applied to plants of "Carmina" raspberry. A variety of "Primocane" or annual raspberry, characterized by a vigorous habit producing large fruits with excellent flavour. The plants were irrigated by drip irrigation system and were almost similar in vigour, free from any visible pathogenic symptoms and at the same bearing phase.

Complete randomized block design was applied with five treatments and four repetitions, therefore 20 experimental units in total. Each block is presented by a planting line of 50 m long and 50 cm wide. The experimental unit is composed of 10 plants, with an inter-plant of 30 cm, and the experimental units of each block are separated by a number of 10 plants considered as borders. Each two blocks (lines) are separated by a border line.

The first used product is a liquid fertilizer that contains calcium in the form of calcium oxide (CaO: 12%) applied in three doses: T1 (100 cc/hl), T2 (200 cc/hl) and T3 (400 cc/hl). The second product is Calcium Nitrate, in granulated form (soluble in water), which contains calcium in the form of calcium oxide (CaO: 26.3%), applied in a single dose T4 (230.8 g/hl). The control treatment (T0) corresponds to plants managed without foliar supply of calcium. Each two applications were separated by 10 days, and harvests were made after 4 and 8 days of treatments.

One tray per experimental unit was collected and weighed and the number of fruits per tray was determined in order to calculate the average weight of a fruit. Firmness was measured according to the method of Eisenhuth. The titratable acidity was determined by diluting 10 g of juice (10 crushed fruits) with 10 ml of distilled water. The titration is carried out using NaOH (0.1 N) until a pH of 8.1 is reached using a pH meter. The evaluation of the sugar content is made by measuring the refractometric index (% Brix) using a digital refractometer and the size of fruits was determined by measuring the polar diameter of a random sample of 10 fruits by elementary plot, using a caliper.

After each harvest, the fruits were placed in a refrigeration chamber at a temperature varying between 0.5 and 4°C and a relative humidity varying between 65 and 80%, for a period of 8 days. The sample was composed of one tray / experimental unit. The trays are weighed before being placed in the refrigeration chamber, then weighed after 3, 5 and 8 days to determine the loss in weight during storage and to assess the effect of foliar calcium treatments. Colour scoring was performed visually on the 3rd, 5th and 8th day postharvest.

Foliar analysis and fruit analysis were carried out to determine the calcium content of leaves and fruits. In addition to calcium, contents of potassium, magnesium, sodium, iron, manganese, zinc and copper were determined. For leaves mineral analysis, a composite sample of five leaves consisting of the 5th leaf from the apex was taken from each experimental unit. The leaves were washed and dried at 60°C for 48 hours, then crushed and the mineral contents were determined using a spectrophotometer. Mineral analysis was performed on a sample of 10 ripe fruits of good commercial quality. The fruits were placed in Petri dishes and dried in at a temperature of 60°C for 7 days. Once dried and crushed, the fruits were subjected to a series of analyses to determine their

mineral content, using a spectrophotometer and following the same protocol adopted for the leaves analysis.

All obtained data during were subjected to analysis of variances (ANOVA) using MiniTab 19 program. Comparison between means was carried out according to Tukey test at probability of 5%.

III. Results And Discussion

The results show that the applied treatments did not significantly impact the average weight of the berries nor their size (Fig. 1 and 2). Past studies in raspberry, kiwi and apple have also shown that Preharvest foliar Ca treatments did not affect fruit weight [8-12].

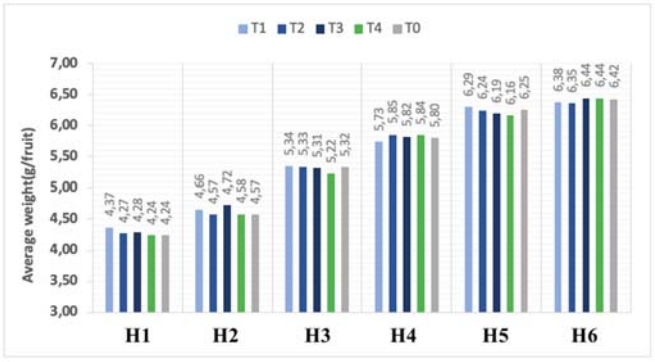

Fig.1. Effect of foliar treatments on the average weight of raspberry fruits during the six harvests.

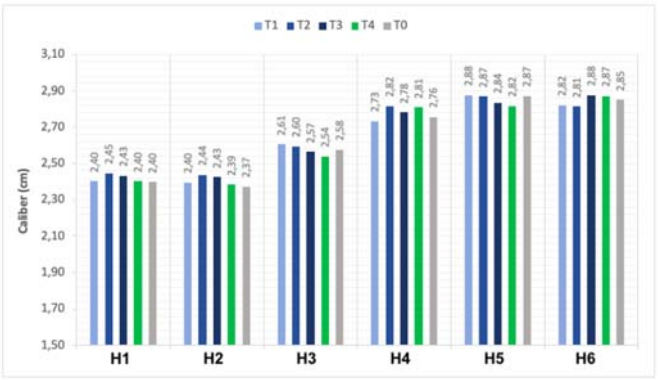

Fig.2. Effect of foliar treatments on raspberry fruit size during the six harvests.

The levels of TSS in the fruits were not significantly affected by the treatments; however, these levels increase, for all the treatments, constantly with the succession of the harvests, this can be due to the increases in temperatures between April and May (Fig. 3). Similar results have been reported by reference [12] on raspberry. Regarding the titratable acidity, no treatment has a significant effect (Fig. 4). Although, a study conducted by reference [13] on strawberry, reported that the foliar treatment based on Ca decreases slightly fruit acidity. While other researchers found that preharvest calcium treatments did not change fruit quality parameters such as TSS and total titratable acidity in cherry and peach [8, 14, 15]. In another study, preharvest calcium treatments increased TSS in cherries but did not affect acidity [16, 17].

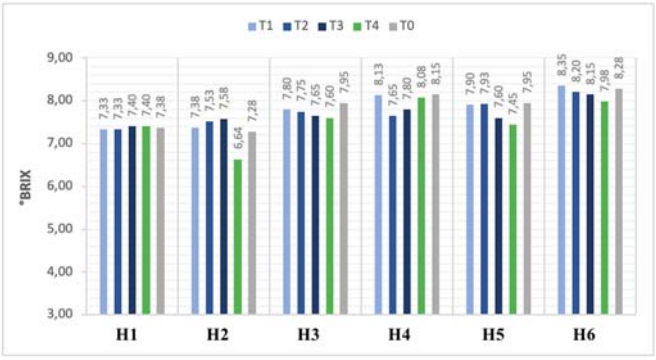

Fig.3. Effect of foliar treatments on the soluble sugar content (TSS) of raspberry fruits during the six harvests.

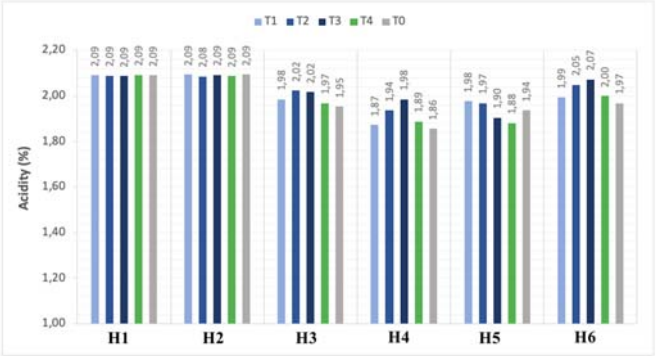

Fig.4. Effect of foliar treatments on the acidity of raspberry fruits during the six harvests.

The firmness was significantly affected by calcium treatments. The treatments with the concentrations of 200 cc/hl and 400 cc/hl of liquid fertilizer (CaO: 12%) (T2 and T3) significantly increased the firmness of the fruits compared to the control (Fig. 5). This was confirmed reference [18] who reported that foliar application of calcium caused during the first harvest, an increase in the firmness of the raspberries of 11 and 13% respectively for the treatments of 2.5ml / l. Ca and 2 ml / l Metalosat, compared to the control and, during the second harvest, an increase in fruit firmness of 11.5 and 10.7% respectively for the treatments 1.7 ml of Ca / l and 2.5 ml of Ca / l, relative to the control. Other researchers reported that preharvest calcium chloride application had no effect on the firmness of cherries [16, 19] or strawberries [20]. The results show also that the fruit firmness decreased significantly from one harvest to the next. Another study conducted by reference [21] showed that the fruits of the last harvests had lower firmness values.

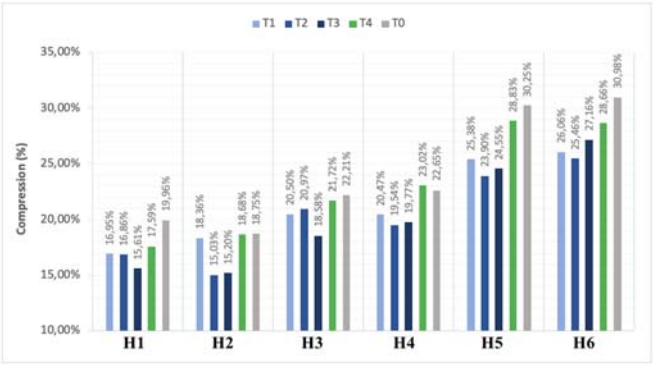

Fig.5. Effect of foliar treatments on the firmness of raspberry fruits during the six harvests.

Regarding fruit weight loss, the study reported a general upward trend for all treatments after 3, 5 and 8 days of each harvest (Table 1). The same results were confirmed by reference [22] who deduced that foliar applications of calcium minimize weight loss during storage. As for the colour of the fruits, the results of our study were significant, the fruits treated with calcium have a less

vivid colouring compared to the control (Fig. 6), and this may be due to the reduction of the chrominance values that were higher for the untreated fruits [23].

Table 1. Results of the statistical analysis of the effect of different factors on average weight loss.

		Average weight loss after 3 days (%)	Average weight loss after 5 days (%)	Average weight loss after 8 days (%)
p-value	Traitement*date	0,980	1,000	1,000
	Traitement	0,327	0,470	0,515
	Date	<0,1%	<0,1%	<0,1%

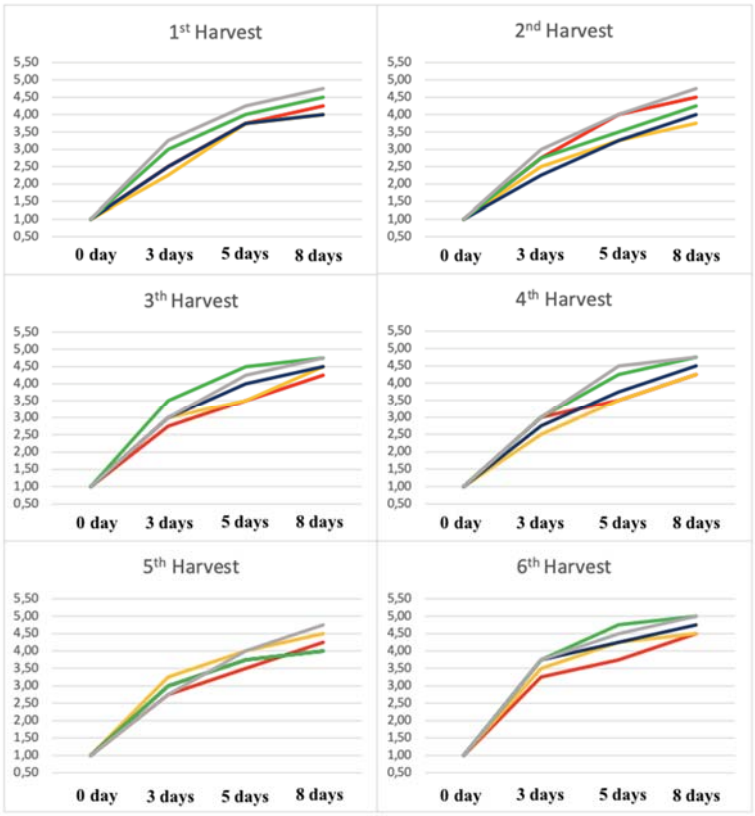

Fig.6. Rating of the colour change in raspberry fruits for the six harvests.

The results also demonstrated that foliar application of calcium increased the calcium content of the leaves, the difference between the content of the leaves of the T2 and T3 plants on the one hand and those of the control on the other hand, was found to be highly significant. The calcium content of fruits was also affected by the treatments, the difference between the fruit content of T2 and control plants was significant. Other past studies in strawberry, blueberry and raspberry have shown that fruit Ca content is not necessarily impacted by foliar Ca applications [24] even when leaf Ca was impacted [12, 25-27]. For other mineral elements, no difference between the treatments was recorded.

IV. Conclusion

Results proved that foliar treatments with the concentrations of 200 cc/hl and 400 cc/hl of liquid fertilizer (CaO: 12%) (T2 and T3) significantly increased the firmness of the fruits of "Carmina" raspberry. The foliar treatments did not have a significant effect on fruit weight, size, soluble sugar content of fruit, acidity and post-harvest weight loss compared to control. The leaves and fruits of the plants subjected to T2 and T3 treatments recorded higher calcium contents compared to control. The results obtained also

show that foliar treatments have the same effect on the quality parameters after 4 and 8 days of treatment.

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