Introduction

Calcium absorption and accumulation in fruit is an important technique to manage and to improve the calcium status of fruit trees in order to achieve the best nutrient balance and to reach a better quality product. Calcium regulates ripening of fruits and stimulates their coloring, ethylene production, and flesh firmness. Optimum concentration of calcium in grape improved fruit quality (Cupta et al., 1980). Calcium deficiency is common in all major fruit growing regions. It is observed even on calcareous soil (Malakouti et al., 1999). It causes many physiological disorders of fruits, such as internal breakdown, senescence breakdown, sunburn, fruit splitting, and rotting (Salisbury and Ross, 1992).

In grape, half of the seasonal requirements of calcium are absorbed from the end of bloom to veraison (Ollat and Gaudillere, 1996). Some studies indicate calcium accumulates in grape berries throughout their development (Schaller et al., 1992; Rogiers et al. 2000), whereas others indicate calcium accumulation stops after veraison (Possner and kliewer, 1985; Cabanne and Doneche, 2003). Therefore, plant Ca requirements must be continually obtained from external sources. It can be said the most effective grapevine treatment increasing berry Ca concentration is foliar application.

Material and Method

This research project was conducted with *Vitis vinivera* cv. 'Asgari' in a commercial 15-year old grapevine, in the province of Fars, Iran, during two growth seasons (2007 to 2008). Ten vines were used per experimental unit within the row, but only the central vines were used for determinations. The five replicates were arranged in a randomized complete block design. Vines were sprayed with a solution containing $CaCl_2x6H_2O$, with point of deliquescence (POD: 33% w/v), and solubility 2790 (g/kg H_2O) at different rates of: 0%, o.8%, 1.2%, 1.6% and 2% w/v $CaCl_2$ (as: T0, T1, T2, T3, and T4) treatments. Sprays were applied in the morning with a volume of 800 L of water ha^{-1} by a handy sprayer until runoff. Spray was repeated three times every two weeks from fruit set to veraison, in each time, sprays of studies Ca materials were made on the same vines. All vines also were fertigated with essential minerals based on the petiole mineral nutrient analyses.

Whole cluster was always sampled from the basal shoots of cane. Samples were collected every two weeks after fruit setting until harvest for each treatment. Fruit samples consisted of 50 to 60 berries per sample. To determine the calcium content of whole berries and of their compartments, berry and rachis samples were washed three times by distilled water, and they were separated each part (skin, flesh, rachis) very carefully by hand. Homogeneity of samples was previously checked by berry size and density (Cabanne and Doneche, 2003). For each date, two lots of washed berries were immediately frozen at -30^0 C until used. The first lot was used for analysis of whole berries, the second lot for analysis of different compartments of the berry (skin, flesh).

Samples were oven dried at 60°C for 48 hours and ground to pass through a 40 mesh screen, and were analyzed for only Ca and K contents. Tissue samples were measured on the acid digested samples (H_2SO_4 + HNO_3) using a spectrophotometer (Varian, AA-40, γ = 422.7 mm, air-acetylene Flame). Calcium and potassium concentrations were reported in mg in 100 g of fresh mass (flesh). Also Ca content in different parts of fruit was expressed in mg of Ca per

berry, and Ca-rachis was calculated in mg in 100g of fresh weight, and K-berry was expressed as ppm. All data were subjected to analysis of variance (ANOVA) procedures and means were separated, using Duncan Multiple range test at *P* _ 0.05, using SAS-PC (ver. 6.12) (SAS Institute, 1990) software.

Results and Discussion

Since there was no significant interaction in calcium accumulation attributes, within two years, results of all two seasons (2007-2008) were combined and only mean values over the two years are presented in this paper. Ca Cl_2 applied increased significantly the Ca content in berry and its compartments (skin, flesh). There was not a linear increment of Ca accumulation in whole berry and berry compartments by different levels of Ca application (Fig. 1). The rate of Ca accumulation during berry development followed a typical sigmoid pattern in the berry of all treatments (Fig. 2). The rate of Ca accumulation was dependant on both the growth phase and the level of Ca applied. The highest rate was recorded at 60 days after anthesis in the high $CaCl_2$ (T4) treatment (Fig. 2).

Calcium accumulation in flesh was more intensive at the 60 days after anthesis in all treatments (included control), than in the early or late growth season (Fig. 4). It was low at the beginning and it declined at the end of growth. Ca accumulation in the berry stopped after 80 days after anthesis (beginning of veraison) in all treatments, while, Ca redistributed from flesh to skin during berry ripening (Figs. 3 & 4). It appeared that the Ca concentration of the berry flesh increased until veraison, then decreased during ripening, whereas, skin Ca content in the skin increased throughout the development of the berries including ripening (Fig. 3).

Ca sprays significantly increase Ca accumulation in berry, but the rates of increase are not proportional to levels of Ca application (Fig. 1). Comparison to whole berry, Ca-rachis is several times, greater than in the fleshy pericarp (pulp). The Ca accumulation in the plant tissues (skin, flesh, rachis) are primarily dependent on the growth season. The highest rates are occurred during 60 to 75 days after anthesis, however they rise as level of $CaCl_2$ increases (Figs. 2, 3, 4, and 5). These results are agreement with previous reports (Cupta et al., 1980; Findlay et al., 1987; Rogiers et al. 2000; Cabanne and Doneche, 2003).

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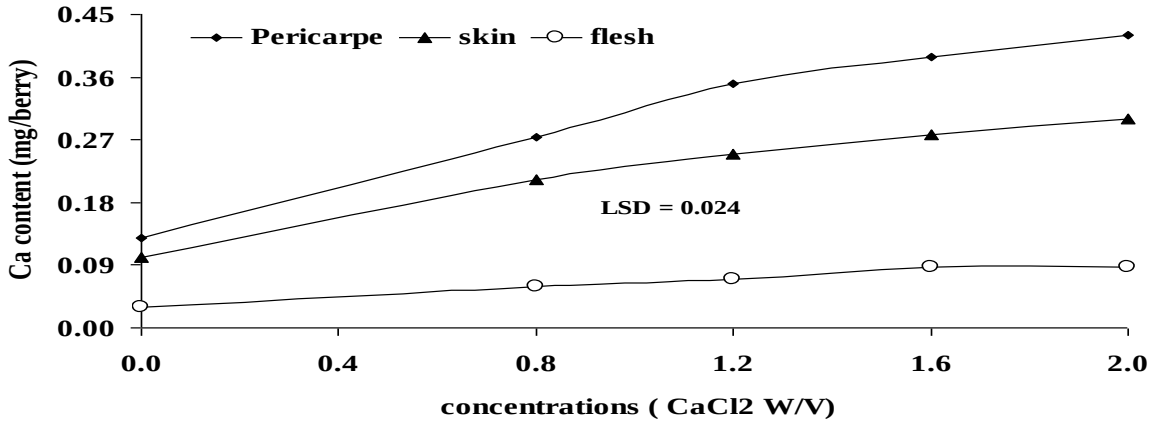

Fig. 1 Comparison of Ca content (mg berry^{-1}) in different parts of grape berry grape.

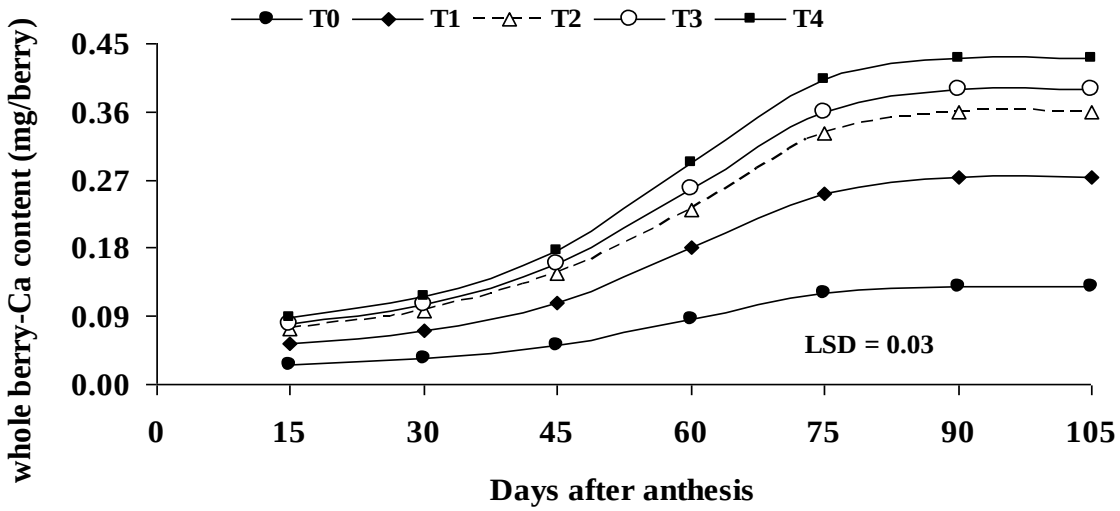

Fig. 2 The rates of whole berry-Ca accumulation (mg berry^{-1}) of grape.

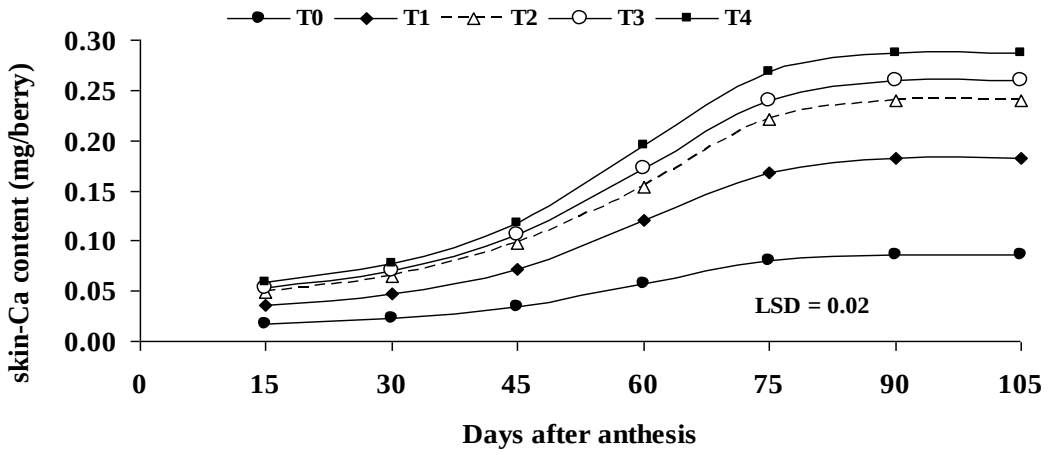

Fig. 3 The rates of skin berry-Ca accumulation (mg berry^{-1}) of grape.

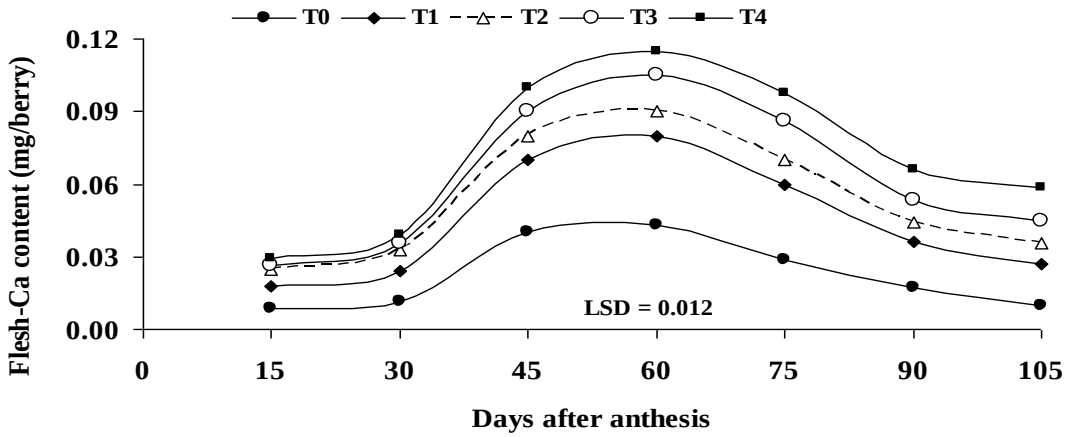

Fig. 4 The rates of flesh-Ca accumulation (mg berry^{-1}) as influenced by 3 times of various levels of $CaCl_2$ (W/V) applications on grape.