Effect of foliar pre-harvest calcium application on the mineral and phytochemical composition of olive oils

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Introduction

Calcium (Ca) is one of the major essential nutrients of the plants, playing important roles on the fruit growth and development, as well as in the quality and firmness maintenance of several fruits and crops as a constituent of cell walls and membranes, providing protection and resistance against pests and diseases [1,2]. The lack of this nutrient in crop plants can cause the decline of their quality and yield, as well as of the shelf life of the corresponding fruits [1]. In humans, the deficiencies in Ca can origin important health disorders, such as hypertension, osteoporosis, and colorectal cancer, which can also cause economic costs [3].

Several studies have shown the effect of the application of Ca on the quality, yield and growth of some fruits, such as strawberry, tomato, and blueberry [4–6]. However, the literature on the high importance of calcium olive nutrition is very scarce, whereby, in this work we intend to study the effect of the pre-harvest foliar application of Ca on the mineral, quality and phytochemical parameters of different monovarietal olive oils during two consecutive harvest years.

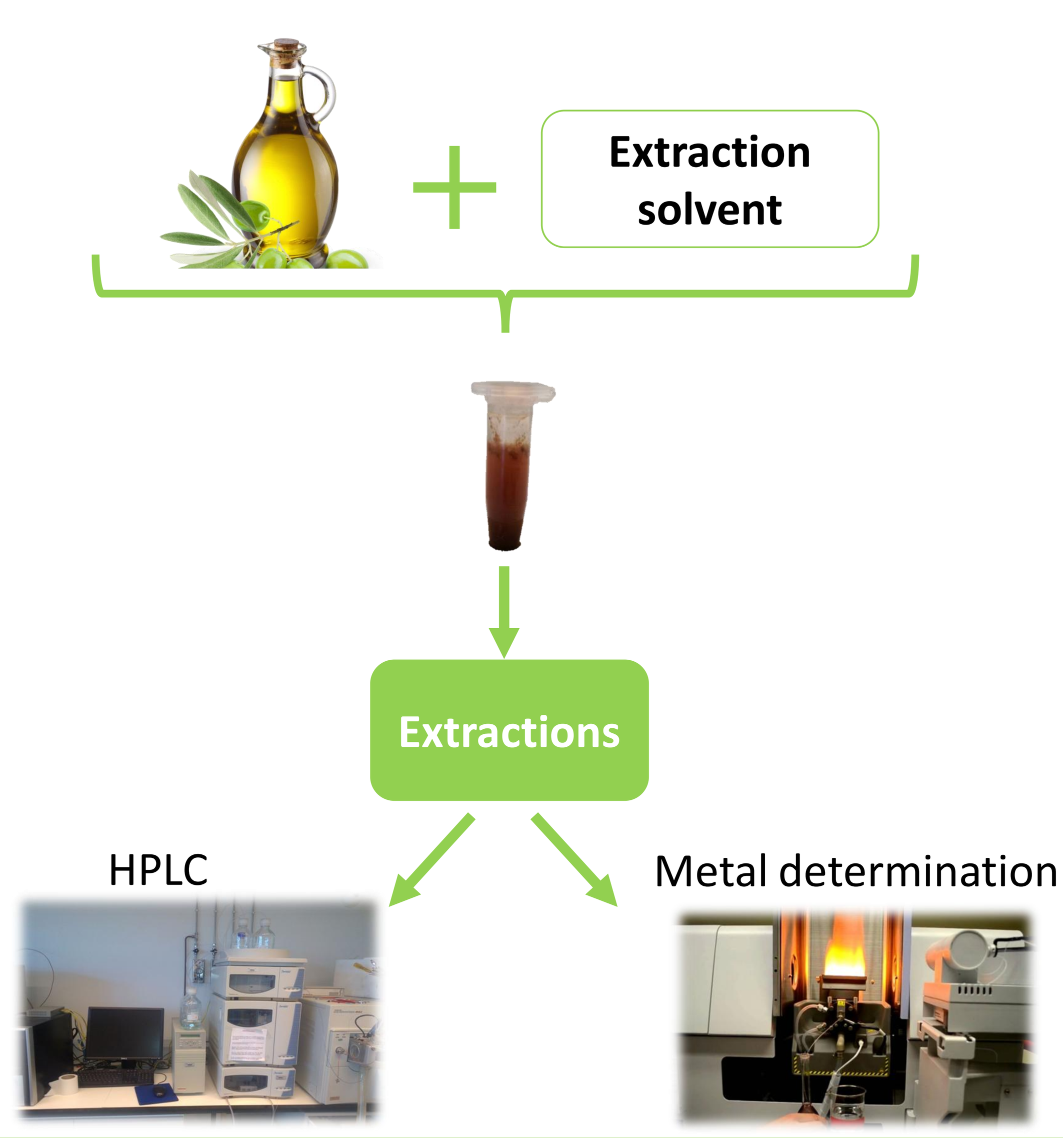
Material and Methods

Samples

The present work was carried on olive trees, from three different cultivars ('Galega Vulgar', 'Cobrançosa', and 'Picual'), on a certified olive grove, at the INIAV located in Elvas, Portugal during the crop seasons 2018 and 2019.

The experimental design included three treatments, Ca fertilization (at two rates: 20g/tree and 40g/tree) and control (with water application), and three replicates with three different trees of comparable age and vigour, evenly spaced between them, within the same growing area, totalizing 9 trees per treatment and 27 marked trees in the total experiment. Calcium rich elemental fertilizer was applied for the first time during both growing seasons at three moments (in August, September, and October), which composition consists in CaO (34% p/p), B (0.8% p/p), and Zn (1.72%, p/p), at a rate of 20g Ca/tree and 40g Ca/tree. Regarding the control samples, corresponding trees (n=9) were used without Ca treatment.

Methodology



Results and Discussion

Ca concentration and quality parameters of olive oils.

Table 1. Quality parameters of olive oils from three cultivars produced after a foliar calcium application at two rates (20g Ca/tree and 40g Ca/tree), including the control samples (water application).

Samples		Acidity (% Oleic acid) 2018	Acidity (% Oleic acid) 2019	Peroxide Index (meq O_2 Kg^{-1}) 2018	Peroxide Index (meq O_2 Kg^{-1}) 2019	ΔK's 2018	ΔK's 2019
Cobrançosa	Control	^{X}0.18 ± 0.02^{abc}	0.17 ± 0.02^{ab}	1.28 ± 0.07^{b}	1.12 ± 0.12^{b}	0.0010 ± 0.0010^{a}	0.0010 ± 0.0010^{a}
	20g Ca/tree	0.24 ± 0.02^{c}	0.21 ± 0.03^{bc}	1.33 ± 0.14^{b}	1.06 ± 0.09^{b}	0.0040 ± 0.0000^{ab}	0.0035 ± 0.0000^{ab}
	40g Ca/tree	0.21 ± 0.01^{bc}	0.21 ± 0.01^{bc}	1.32 ± 0.26^{b}	1.07 ± 0.13^{b}	0.0047 ± 0.0006^{b}	0.0037 ± 0.0006^{ab}
Galega	Control	0.13 ± 0.01^{a}	0.15 ± 0.01^{ab}	1.18 ± 0.47^{ab}	0.99 ± 0.11^{ab}	0.0010 ± 0.0010^{a}	0.0012 ± 0.0010^{a}
	20g Ca/tree	0.17 ± 0.01^{ab}	0.17 ± 0.01^{ab}	0.80 ± 0.14^{ab}	0.97 ± 0.12^{ab}	0.0023 ± 0.0006^{ab}	0.0019 ± 0.0006^{ab}
	40g Ca/tree	0.15 ± 0.03^{ab}	0.17 ± 0.02^{ab}	0.84 ± 0.08^{ab}	0.86 ± 0.03^{a}	0.0020 ± 0.0000^{ab}	0.0022 ± 0.0006^{ab}
Picual	Control	0.16 ± 0.01^{ab}	0.13 ± 0.00^{a}	2.22 ± 0.38^{c}	1.75 ± 0.21^{c}	0.0020 ± 0.0020^{ab}	0.0017 ± 0.0020^{ab}
	20g Ca/tree	0.17 ± 0.01^{ab}	0.15 ± 0.01^{ab}	1.19 ± 0.23^{b}	1.38 ± 0.17^{bc}	0.0053 ± 0.0025^{b}	0.0035 ± 0.0011^{b}
	40g Ca/tree	0.19 ± 0.05^{abc}	0.17 ± 0.02^{ab}	0.62 ± 0.08^{a}	1.08 ± 0.09^{b}	0.0047 ± 0.0006^{b}	0.0041 ± 0.0006^{b}
P-value		^{Y}**		***		**	

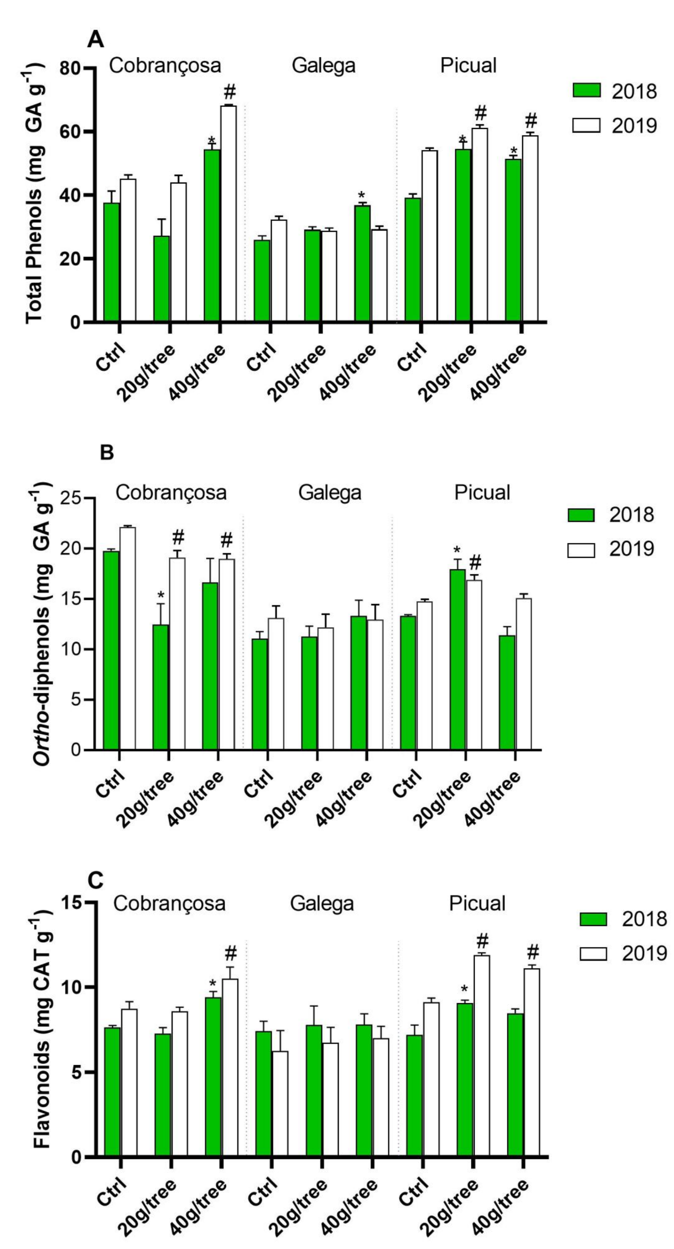
^{X} The values are presented as mean ± standard deviation (n = 3). Different letters indicate significantly different results (Tukey's test, p < 0.05).
^{Y} Significance: non-significant, N.S. (p > 0.05); * significant at p < 0.05; ** significant at p < 0.01; *** significant at p < 0.001.

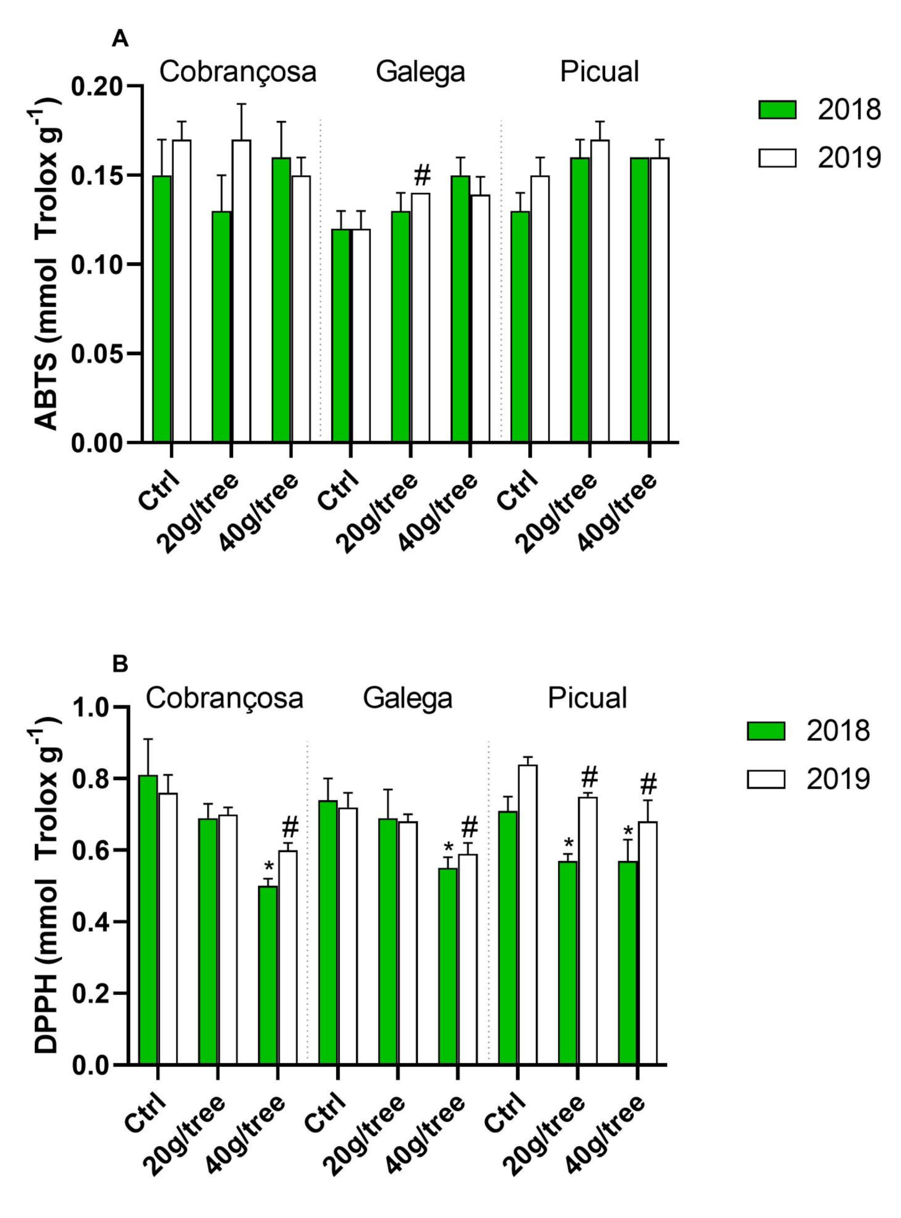
Table 2. Calcium concentration of olive oils from three cultivars produced after a foliar calcium application at two rates (20g Ca/tree and 40g Ca/tree), including the control samples (water application).

Samples		Calcium (g Kg^{-1}) 2018	Calcium (g Kg^{-1}) 2019
Cobrançosa	Control	^{X}1.25 ± 0.02^{ab}	1.12 ± 0.02^{b}
	20g Ca/tree	1.48 ± 0.13^{bc}	1.51 ± 0.10^{bc}
	40g Ca/tree	1.36 ± 0.02^{abc}	1.45 ± 0.08^{bc}
Galega	Control	1.20 ± 0.14^{ab}	1.18 ± 0.09^{bc}
	20g Ca/tree	1.83 ± 0.12^{c}	1.77 ± 0.09^{d}
	40g Ca/tree	1.58 ± 0.25^{bc}	1.71 ± 0.12^{d}
Picual	Control	1.49 ± 0.00^{bc}	1.25 ± 0.01^{bc}
	20g Ca/tree	0.92 ± 0.15^{a}	1.01 ± 0.01^{a}
	40g Ca/tree	1.13 ± 0.01^{ab}	1.22 ± 0.01^{bc}
P-value		^{Y}**	**

^{X} The values are presented as mean ± standard deviation (n = 3). Different letters indicate significantly different results (Tukey's test, p < 0.05).
^{Y} Significance: non-significant, N.S. (p > 0.05); * significant at p < 0.05; ** significant at p < 0.01; ***

Phenolic composition of olive oils and their antioxidant activity.





Phenolic compounds identified by HPLC.

Table 3. Phenolic profile of olive oils from three cultivars produced after a foliar calcium application at two rates (20g Ca/tree and 40g Ca/tree), including the control samples (water application).

Identification		Hydroxytyrosol (mg g^{-1})		Tyrosol (mg g^{-1})		Oleuropein (mg g^{-1})		Luteolin (mg g^{-1})	
RT (min)		9,99		17,12		28,38		32,45	
		2018	2019	2018	2019	2018	2019	2018	2019
Cobrançosa	Control	^{X}6,87 ± 0,58^{cd}	9.83 ± 0.65^{b}	3,03 ± 0,80^{c}	2.04 ± 0.50^{bc}	1,91 ± 0,22^{ab}	2.35 ± 0.21^{b}	0,28 ± 0,08^{ab}	0.79 ± 0.12^{bc}
	20g Ca/tree	8,89 ± 1,99^{d}	12.38 ± 1.04^{c}	6,49 ± 1,32^{d}	7.71 ± 0.31^{a}	3,43 ± 0,74^{c}	3.99 ± 0.30^{d}	1,73 ± 0,30^{c}	1.46 ± 0.09^{de}
	40g Ca/tree	5,87 ± 0,91^{abc}	9.03± 0.35^{b}	2,84 ± 0,15^{bc}	2.37 ± 0.31^{cd}	1,89 ± 0,30^{ab}	3.06 ± 0.06^{c}	0,19 ± 0,03^{ab}	0.55 ± 0.29^{abc}
Galega	Control	3,41 ± 0,13^{a}	4.22 ± 0.38^{a}	1,74 ± 0,14^{abc}	1.28 ± 0.11^{ab}	0,79 ± 0,07^{a}	1.05 ± 0.06^{a}	0,13 ± 0,01^{a}	0.10 ± 0.01^{a}
	20g Ca/tree	3,60 ± 0,77^{ab}	4.80 ± 0.95^{a}	0,77 ± 0,19^{a}	1.01 ± 0.02^{a}	0,64 ± 0,00^{a}	0.75 ± 0.07^{a}	0,74 ± 0,11^{b}	0.61 ± 0.09^{abc}
	40g Ca/tree	3,67 ± 0,15^{ab}	5.37 ± 1.15^{a}	1,74 ± 0,01^{abc}	1.29 ± 0.19^{ab}	1,41 ± 0,42^{ab}	1.17 ± 0.05^{a}	0,33 ± 0,00^{ab}	0.35 ± 0.09^{ab}
Picual	Control	6,70 ± 0,73^{cd}	10.93 ± 0.25^{bc}	2,95 ± 0,12^{bc}	3.08 ± 0.04^{d}	2,40 ± 0,36^{bc}	2.43 ± 0.13^{c}	2,38 ± 0,17^{d}	2.26 ± 0.25^{f}
	20g Ca/tree	4,38 ± 0,47^{abc}	9.17 ± 0.60^{b}	1,08 ± 0,04^{ab}	1.65 ± 0.21^{abc}	1,05 ± 0,49^{a}	0.93 ± 0.13^{a}	1,97 ± 0,25^{cd}	1.86 ± 0.15^{ef}
	40g Ca/tree	6,12 ± 0,68^{bc}	9.47 ± 0.49^{b}	1,37 ± 0,13^{abc}	1.85 ± 0.07^{abc}	0,80 ± 0,44^{a}	1.00 ± 0.11^{a}	0,29 ± 0,18^{ab}	0.92 ± 0.06^{cd}
	P-value	^{Y}***	***	***	***	**	***	**	***

^{X} The values are presented as mean ± standard deviation (n = 3). Different letters indicate significantly different results (Tukey's test, p < 0.05).
^{Y} Significance: non-significant, N.S. (p > 0.05); * significant at p < 0.05; ** significant at p < 0.01; *** significant at p < 0.001.
RT - Retention Time

Conclusions

In this work, it was possible to understand the effect of calcium foliar application in olive trees on the phytochemical, mineral and quality parameters of the respective olive oils produced at two harvest seasons. This mineral application revealed to influence all these parameters, as well as the cultivar that demonstrated to affect the different results obtained.

Calcium is considered an important nutrient for plant height and development, but scarce are the studies regarding its influence on the secondary metabolism of plants. A rate application of 20g Ca/tree resulted in an increase of Ca and phenolic compounds of some olive oils cultivars, while 40g Ca/tree caused an increase of these parameters for other cultivars, highlighting the importance of controlling the nutrient concentration to be applied in the field.

Furthermore, some phenolic compounds and the antioxidant activity of some olive oils were negatively affected with the Ca foliar application, demonstrating not only the high influence of cultivar factor, but also the mineral effect on the oxidative enzymes activities.

Thereby, the supplementation of calcium or other nutrients in plants could be considered a good way to improve the quality and some phytochemical characteristics of the final products.

Acknowledgements

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