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RESEARCH ARTICLE

Effects of decreasing levels of n amendments on organic "granny smith" apple trees

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Abstract

The effect of decreasing levels of organic N-fertilization on fruit production, mineral composition and fruit quality was evaluated in organically cultivated "Granny Smith" apples trees. Treatments included the application of decreasing levels of N fertilization (100 kg N ha^{-1}, 75 kg N ha^{-1}, 50 kg N ha^{-1} and 0 kg N ha^{-1}) applied as fossilized red guano (50% of the total amount of N) and blood meal (50% of the total amount of N) to twelve years old Granny Smith apple trees. Yield was not affected by the treatments (yield ranged from 0.28 to 0.4 kg cm^{-2} SCSA). Fruit mineral concentration and ratios were not affected by treatments. Fruits showed low Ca concentrations (2.8 to 3.3 mg Ca 100 g^{-1} FW), high levels of K (118.6 to 130.1 mg K 100 g^{-1} FW) and high values for K+Mg/Ca (> 12) and K/Ca (> 30) ratios. Mineral concentration on leaves was not affected by treatments (normal concentrations for macro and microelements). Bitter pit was only detected after 60 days of storage (100 kg N ha^{-1} tree, 1.1 in a scale 1-4). Besides orchard nitrogen management, fruit mineral ratios and Ca foliar applications should be considered for managing fruit production and quality in organic apples.

Keywords: *Malus domestica*, physiological disorders, volcanic soils, Ca, Mg, K.

1. Introduction

Apple is considered to be one of the most important fruit crops in Chilean organic production. While there are no official statistics, the AAOCH (Chilean Organic Agriculture Association – Agrupación de Agricultura Orgánica de Chile) estimates an area of about 1300 ha dedicated to certified organic apple production. Organic farming is a form of agriculture which excludes the use of synthetic fertilizers and pesticides, plant growth regulators and genetically modified organisms (Stockdale *et al*., 2001). Organic apple production has grown rapidly since the mid 1990s and the demand continues to outstrip supply, which shows consumers preferences towards high quality fruit (Weibel and Häseli, 2003).

Concerning the plant nutrition management, organic farming aim to protect the long-term fertility of the soil and to supply plants with necessary nutrients through natural or organic amendments and fertilizers (Herencia *et al*., 2007). There is a wide array of organic N sources available, but they vary in cost, N content, and N availability (Gaskell and Smith, 2007). Among the allowed N organic amendments we can find sources such as fossilized red guano and blood meal, which have been profusely applied in Chilean organic apple orchards. The use of these products may improve soil fertility but it is difficult to estimate the overall input-output nutrient budget of the crop, due to the inconsistent composition of these organic supplements (Herencia *et al*., 2007). Due to these difficulties, high amounts of organic N sources are generally applied in organic apple production in order to supply adequate nitrogen to fulfil the needs of the apple tree for a full production. In general, oversupply of nitrogen is more a problem in an apple orchard than undersupply (Neilsen and Neilsen, 2003). An excess of N can lead to potential leakage to the environment of excess nitrogen that is not taken up by trees. In the tree an oversupply of N can lead to excessive vigour and poor quality characteristics (Faust, 1989) derived from a greater incidence of storage disorders, such as bitter pit among others (Nava and Dechen, 2009; De Freitas and Mitcham, 2012). Bitter pit may be considered the main physiological disorder affecting apples (Torres *et al.,* 2015). Bitter pit, occur frequently in organic apple production, where foliar treatments with Ca are restricted and where high amounts of organic N sources are applied (Weibel, 2001). Although a number of studies are available on organic production of apples, only limited information is available on the impact of decreasing levels of N amendments on growth, fruit yield and quality of apples. Based on the described above, the objective of our research was to evaluate the effect of decreasing levels of organic N-fertilization on fruit yield and quality, vegetative growth and mineral composition of organically cultivated "Granny Smith" apples.

2. Material and Methods

2.1. Characteristics of the site

The study was carried out during 2009 and 2010 in the Maule Region of Chile (34.6ºS, 71.1ºW). The soil at the site belongs to the Romeral soil Series (Humic Haploxerands) (Casanova *et al*., 2007). The soil was a loam, 80 cm depth. The soil chemical properties were determined at the beginning of the study considering the superficial layer (0-20 cm). Analyses were carried out according to the methods described by Sadzawka *et al*. (2000). Soil mineral analysis showed the following results: Available N (21 mg kg^{-1}), K (67 mg kg^{-1}), P (15 mg kg^{-1}), pH-H_2O (6.4), O.M (4.8%), EC (1.2 dS m^{-1}). Other selected fertility characteristics of orchard soil profile at the experimental site are presented in Table 1.

Table 1. Selected fertility characteristics of orchard soil profile at the experimental site

Properties	Depth (0 – 20 cm)
	Values
OM (%)	4.80
pH ($H_2$0)	6.40
EC (dS m^{-1})	1.20
Olsen P (mg kg^{-1})	15.0
Available N (mg kg^{-1})	21.0
Available K (mg kg^{-1})	67.0
Al ($cmol_c$ kg^{-1})	0.02
Al saturation (%)	0.20
Ca ($cmol_c$ kg^{-1})	7.70
Ca saturation (%)	34.00
Mg ($cmol_c$ kg^{-1})	1.70
Mg saturation (%)	10.00
K ($cmol_c$ kg^{-1})	0.10
K saturation (%)	0.69
Na ($cmol_c$ kg^{-1})	0.30
Na saturation (%)	1.30

The climate of the region is characterized as Mediterranean, with the rainy season occurring primarily during winter months, while the summer is quite dry. Mean annual precipitation is 700 mm. Mean annual temperature in the region is 15 °C.

Plant material consisted of 'Granny Smith' apple trees, planted in 1998 on 'MM 106' rootstock, spaced 4 × 2 m in north to south row and trained to a Solaxe system. Trees have been organically cultivated since 2005. All sample trees were of uniform size and without any visible symptoms of either disease or pest infestation at the time of trial initiation. Trees were irrigated with under-tree microsprinklers weekly from November to late March. Organic allowed farming practices (irrigation, fertilization, pest and weed control, and dormant pruning) were followed every year.

Trees were assigned to a completely randomized design with ten individual trees as replications. Analysis of variance was conducted using the JMP program packaged and means were compared using the Tuckey test at 0.005.

2.2. Fertilization treatment

Treatments included the application of decreasing levels of N fertilization (100 kg N ha^{-1}, 75 kg N ha^{-1}, 50 kg N ha^{-1} and 0 kg N ha^{-1}) incorporated as fossilized red guano (2,5 % N), 50% of the total amount of N and blood meal (14% N), 50% of the total amount of N . Treatments and total amounts used for each organic fertilizer are presented in Table 2.

N organic substances were applied 50% during early spring and 50% during early summer. All materials were applied in a 0.9 radius around the tree trunk, incorporated with soil, and then watered. All treatments included also additional standard fertilization with commercial products allowed for use in certified organic production and presented in Table 3.

The following measurements and observations were performed:

Table 2. N amendment treatments in organically cultivated "Granny Smith" apple trees. Rates and combinations of each amendment

Treatment	Total N	Fossilized red guano	Blood meal	Fossilized red guano (2,5 % N)	Blood meal (14% N)
	N (kg ha^{-1})	N (kg ha^{-1})	N (kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})
100 kg N ha^{-1}	100.0	50.0	50.0	2000.0	333.3
75 kg N ha^{-1}	75.0	37.5	37.5	1500.0	267.9
50 kg N ha^{-1}	50.0	25.0	25.0	1000.0	178.6
0 kg N ha^{-1}	0.0	0.0	0.0	0.0	0.0

Table 3. Additional fertilization program with commercial products allowed for use in certified organic apple production.

Commercial product	Active ingredient	Dose/rates
Potassium sulphate	KSO_4	163 kg ha^{-1}
Rock phosphate	P205 mainly	183 kg ha^{-1}
Calcium sulphate	$CaSO_4$	3 ton ha^{-1}
Calcium bionutrient	Ca	1 L ha^{-1}
Boron bionutrient	B	1 L ha^{-1}
Zinc bionutrient Zinc +	Zinc, Nitrogen	0.75 L ha^{-1}
Kelpac L2414	*Ecklonia* algae	3 L ha^{-1}
Metalosate	Aminoacid quelates	750 cm^3 ha^{-1}
Calcium metalosate	Aminoacid quelates + Ca	1 kg ha^{-1}
Zinc metalosate	Aminoacid quelates + Zn	500 g ha^{-1}

2.3. Fruit yield assessment

Fruit was harvested according to Streif's index [firmness/ (percentage soluble solids concentration x starch index)]. Fruit was harvest when the Streif index showed values over 0.35.

Two branches (oriented north and southwards) were chosen and marked from each tree before the N amendments application. At harvest branch cross sectional area (BCSA) was calculated and the crop from each branch was weighed. The yield efficiency was calculated as: Fruit number per branch /BCSA (cm^2), kg yield/ BCSA (cm^2) and mean fruit weight (kg).

Fruit yield was measured separately for each tree and branch and fruits were classified according to fruit diameter in three different fruit sizes: Small = < 70 mm, medium=70-80 mm and large = > 80 mm. Firmness was measured on 12 fruits per tree using a Mc Cormick firmness-tester with an 11-mm tip on the blush and opposite side of each apple.

2.4. Fruit quality assessment

Fruit quality assessment considered fruits of homogeneous size. Soluble solids concentration percentage (SSC) was determined using an Atago-1 hand held refractometer with automatic temperature compensation, at 22 °C in juice squeezed from the homogenate of the 12 fruit sampled for flesh firmness. Starch index of fruit was estimated by iodine test using a scale of 1 (100% of cross section area stained) to 10 (0% of area stained); fruit ground color was measured using a 1 to 6 scale (Winter *et al*., 1981), fruit cover color was measured using a scale from 1 (blush <25% of fruit skin surface) to 5 (blush >76% of skin surface). Flesh firmness and SSC of fruit after storage were measured on 12 fruits per tree. Apple fruits were stored for 30 and 60 days in refrigerated air storage at 1–2°C and a relative air humidity of 88–90%. Measurements were performed after fruit was removed from storage and then kept in room at 18–20 °C for 5 days. The incidence of physiological disorders (bitter pit, water core, internal breakdown, scald) and diseases were assessed on the 12 fruits per tree and using a 1 to 4 scale according to the methodology described by Von Bennewitz *et al*., (2011). The severity was assessed by classifying each apple according to a grading of its physiological disorders-like symptoms. For bitter pit: level 1, healthy fruit; level 2, when the fruit had between 1 and 6 pits on its surface; level 3, or moderate, when less than one-third of the surface of the fruit was affected; and level 4, or severe, when more than one-third of the surface of the fruit was affected.

2.5. Fruit mineral concentration

Fruit mineral analyses were carried out to determine the concentration of N, P, K, Mg, Ca, and B in fruit tissues: Fruits were collected when Streif 's index showed values over 0.35. Apples of similar diameter from each tree were randomly collected from the central zone of the tree crown. Fruits were then rinsed with 0.01M HCl and then with double-deionized water. Seeds and stems were removed and two quarters of the apple were cut out from opposite sides. The fruit samples were dried at 75 °C for 72 h and ground to pass a 40-mesh screen. Nitrogen was determined according to the Kjeldahl method. In order to determine P, K, Ca, and Mg, fruit samples were digested in 9:1 (v=v) mixture of HNO_3 and $HClO_4$ or ashed in a muffle furnace at 480 °C for 12 hours. Boron, Potassium, Magnesium and Calcium were determined with the aim of an Atomic absorption spectrophotometer and P was determined colorimetrically by the vanado-molybdo-phosphoric method. Concentrations of nutrients in fruit tissues were expressed in relation to dry weight (DW).

2.6. Leaf analysis

Leaves were collected from the mid-region of current season shoots after terminal bud formation in mid-January. Leaves were washed in detergent, rinsed in deionized water, dried at 65°C, and ground in a grinder. Wet digestion was used for organic matter destruction in the case of N, P, K, Ca, Mg and dry ashing for Fe, Mn, Cu and Zn. Nitrogen was determined according to the Kjeldahl method, P was determined colorimetrically by the vanado-molybdo-phosphoric method and Potassium, Magnesium, Calcium and Boron were determined with the aim of an Atomic absorption spectrophotometer.

2.7. Vegetative growth

Branch cross-sectional area (BCSA) and seasonal shoot extension growth were measured during 2009 and 2010 in two marked branches (oriented north and southwards) from each tree.

2.8.Statistical analysis and experimental design

Data were subjected to analysis of variance (ANOVA) in a completely randomized design with four treatments and ten replicates per treatment (1 replicate=1 tree). Mean separation was done by Duncan's multiple range test at 5 and 1% levels of significance. Statistical procedures were performed using SAS software. The percentage for fruit diameter distribution, apples with physiological disorders and diseases and fruit color were calculated following data transformation according to the Bliss function (y=arc sinx).

3. Results

"Granny smith" apple tree cropping was not influenced by the treatments during the first (2009) and second year (2010) of the study and yielded on average 2.1 and 1.3 Fruits/BCSA (cm^2) respectively (Table 4).

Fruit firmness and the starch index were not affected by treatments during both years at harvest, 30 and 60 days after harvest (Table 5). In general, apple firmness decreased only slowly, 30 and 60 days after harvest. The values for the starch index increased during storage as a consequence of the natural starch breakdown in fruits

As for mineral content in fruits, only N and K concentration was affected by treatments, but only during the second year of study (Table 6). Mineral ratios (N/Ca,K/Ca,Mg/Ca, K+Mg/Ca) were not affected by treatments (Table 7).

In the year of the study, leaf mineral concentrations were not significantly affected by treatments (Table 8).

Table 4. Effects of different organic N fertilization treatment on fruit yield in organically cultivated "Granny smith" apples.

Organic N fertilization treatment	Fruit number/BCSA (cm^2)		Yield, kg/BCSA (cm^2)		Mean fruit weight (kg)	
	2009	2010	2009	2010	2009	2010
100 kg N ha^{-1}	2.40 a	1.14 a	0.46 ab	0.17 a	0.20 a	0.15 a
75 kg N ha^{-1}	1.59 a	1.20 a	0.30 b	0.18 a	0.19 a	0.15 a
50 kg N ha^{-1}	1.64 a	1.11 a	0.32 ab	0.16 a	0.20 a	0.15 a
0 kg N ha^{-1}	2.84 a	1.71 a	0.55 a	0.26 a	0.19 a	0.15 a
Mean	2.11	1.29	0.40	0.19	0.19	0.15

Means followed by the same letter do not differ at $p = 0.05$ according to Duncan's multiple range test.

Table 5. Effects of different Organic N fertilization treatments on fruit characteristics in organically cultivated "Granny smith" apples (at harvest, 30 and 60 days after harvest).

Period of evaluation/treatment	Firmness (kg)		TSS º Brix		Starch index (1-6)		Fruit ground color (1-4)	
At harvest	2009	2010	2009	2010	2009	2010	2009	2010
100 kg N ha^{-1}	7.8 a	7.9 a	11.7 ab	12.0 a	1.9 b	3.0 a	1.6 ab	1.2 a
75 kg N ha^{-1}	8.1 a	8.0 a	12.4 a	12.7 a	2.9 a	2.9 a	2.3 a	1.3 a
50 kg N ha-1	7.9 a	7.8 a	11.6 b	12.5 a	2.7 a	3.1 a	1.9 ab	1.4 a
0 kg N ha^{-1}	7.8 a	7.9 a	11.7 ab	11.8 a	2.7 a	3.0 a	1.3 b	1.3 a
30 days after harvest	2009	2010	2009	2010	2009	2010	2009	2010
100 kg N ha^{-1}	7.4 a	7.5 a	12.4 a	12.6 a	4.1 a	3.0 a	1.4 a	1.1 a
75 kg N ha^{-1}	7.6 a	7.2 a	12.0 a	12.6 a	3.9 a	2.9 a	1.6 a	1.1 a
50 kg N ha^{-1}	7.6 a	7.4 a	11.4 b	11.6 a	4.1 a	3.1 a	1.6 a	1.3 a
0 kg N ha^{-1}	7.7 a	7.6 a	11.9 ab	13.1 a	3.9 a	3.0 a	1.8 a	1.2 a
60 days after harvest	2009	2010	2009	2010	2009	2010	2009	2010
100 kg N ha^{-1}	7.4 a	7.5 a	12.4 a	12.6 a	4.1 a	3.0 a	1.4 a	1.1 a
75 kg N ha$_{-1}$	7.6 a	7.2 a	12.0 a	12.6 a	3.9 a	2.9 a	1.6 a	1.1 a
50 kg N ha^{-1}	7.6 a	7.4 a	11.4 b	11.6 a	4.1 a	3.1 a	1.6 a	1.3 a
0 kg N ha^{-1}	7.7 a	7.6 a	11.9 ab	13.1 a	3.9 a	3.0 a	1.8 a	1.2 a

Means followed by the same letter do not differ at $p = 0.05$ according to Duncan's multiple range t-test. TSS, total soluble solids

Table 6. Effects of different Organic N fertilization treatments on fruit nutrient concentration (mg/100g FW).

Treatments	N		P		K		Ca		Mg	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
100 kg N ha^{-1}	35.7 a	92.8 a	11.5 a	14.7 a	130.1 a	155.2 a	3.0 a	4.9 a	4.0 a	9.3 a
75 kg N ha^{-1}	47.0 a	85.1 ab	11.6 a	13.3 a	132.4 a	131.3 b	2.8 a	5.3 a	4.5 a	8.4 a
50 kg N ha^{-1}	46.7 a	74.6 c	10.9 a	13.3 a	118.9 a	136.6 ab	2.9 a	5.8 a	4.2 a	8.4 a
0 kg N ha^{-1}	48.8 a	78.6 bc	10.4 a	13.8 a	118.6 a	146.2 ab	3.3 a	5.2 a	4.3 a	9.4 a

Means followed by the same letter do not differ at $p = 0.05$ according to Duncan's multiple range test.

Table 7. Effects of different Organic N fertilization treatments on fruit nutrient ratios.

	N/Ca		K/Ca		Mg/Ca		K+Mg/Ca	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010
100 kg N ha^{-1}	12,18 a	18.93 a	44.70 a	31.67 a	1.50 a	1,89 a	45.56 a	33.57 a
75 kg N ha^{-1}	16.97 a	16.06 a	48.21 a	24.77 a	1.61 a	1.58 a	49.83 a	26.35 a
50 kg N ha^{-1}	16.43 a	12.86 a	41.50 a	23.55 a	1.46 a	1.45 a	42.95 a	24.99 a
0 kg N ha^{-1}	14.81 a	15.12 a	35.70 a	28.11 a	1.29 a	1.81 a	36.99 a	29.91 a

Means followed by the same letter do not differ at $p = 0.05$ according to Duncan's multiple range test.

Table 8. Effects of different Organic N fertilization treatments on mineral concentrations in leaves (% DW). Year 2009.

Treatments	N	P	K	Ca	Mg	Mn	Zn	Cu	Fe	B
100 kg N ha^{-1}	2.13 a	0.20 a	1.08 b	1.09 a	0.32 a	30.30 a	15.30 a	10.00 a	146.7 a	51.3 a
75 kg N ha^{-1}	2.16 a	0.21 a	1.15 ab	1.09 a	0.29 a	29.30 a	15.30 a	10.00 a	144.3 a	34.7 a
50 kg N ha^{-1}	2.12 a	0.23 a	1.24 a	1.16 a	0.30 a	30.30 a	15.30 a	10.30 a	150.3 a	34.0 a
0 kg N ha^{-1}	2.10 a	0.21 a	1.14 ab	1.08 a	0.31 a	27.70 b	14.30 a	10.00 a	106.3 a	71.7 a

Means followed by the same letter do not differ at $p = 0.05$ according to Duncan's multiple range t-test.

4. Discussion

The obtained fruit load values may be considered low according to Yuri *et al*. (2008). These authors consider values up to 4 fruits/BCSA (cm^2) as a low fruit load for apples. Regarding the yield expressed as kg of fruit/BCSA (cm^2) treatments yielded an average of 0.4 and 0.2 fruits/BCSA (cm^2) which represents 65 and 54 tons fruit/ha respectively which could be consider a medium yield in organic apple orchards. For conventional apple orchards, under Chilean agro climatic conditions, these yields may be considered low if we compare them with orchards of the same age and rootstock, where it is possible to reach yields of more than 100 ton fruit/ha. Mean fruit weight was also not affected by treatments, but a considerable reduction in fruit mean weight was observed for the second season 0.2 kg (2009) and 0.15 kg (2010). Treatments also had no effect on fruit diameter distribution. 55% of the fruit yield was concentrated in the medium size (70-80 mm of fruit diameter), which obtained the best prices, followed by the big (> 80 mm): 26.17% and small (<70 mm): 21.24% sizes.

Soluble solids concentration was affected by treatments only during the first year. Soluble solids concentrations were significantly lower in the case of the treatment with 50 kg N ha^{-1}. As reported by Amiry and Fallahi (2009) a reduction in the total amount of N applied as organic amendment tends to reduce the soluble solids concentration in fruits. In some cases soluble solids concentration increased during storage, possibly as a result of water loss from the fruits. In this study soluble solids concentration was not related to K concentration in fruits, and fruit firmness was not related to K/Ca ratio in fruits as was reported by Dilmaghani *et al*. (2004). In general, apple firmness tended to decrease only slowly after 60 days of storage. A decrease in fruit SSC with storage has previously been reported by other authors (Shababi and Malakouti, 2000; Tagliavini *et al*., 2000).

The mineral concentration in fruits for most of the other studied elements (P, Ca, Mg, Mn, Zn, Cu, Fe, B) was not influenced by treatments. Fruits nitrogen mineral concentration was significantly reduced during the second year reduced in the case of none and 50 kg N ha^{-1} treatments, in comparison to 75 and 100 kg N ha^{-1}. This reduction in fruit N concentration did not result in a decrease of fruit yield, fruit size or other fruit quality parameters. During the first year, N concentration in fruits was adequate according to standards of Shear (1980) who suggested N concentration (FW Basis) of 54 mg 100 g^{-1} as the limit to avoid physiological disorders like bitter pit. Nielsen and Nielsen (2003) suggested N critical nutrient concentration (FW Basis) ranging from 50-70 mg 100 g^{-1} to be considered as adequate. With averages of 44 mg 100 g^{-1} during the first year, N fruit concentration in the present study were below this concentration, but during the second year reached average values of 82.7 mg 100 g^{-1}. This high N concentration value imposes risks to the development of physiological disorders like bitter pit, even though the incidence of bitter pit during this year was very low. Lower N concentration in fruits, observed in treatments with doses of 0 kg N ha^{-1} and 50 kg N ha^{-1} may contribute to decrease this risk.

Although Ca is likely the most abundant cation taken by apple trees (Tagliavini *et al*., 2000), the amounts of Ca partitioned into fruits were relatively small (Table 9); this is evident when comparing the Ca concentration in fruits (average 0.03 % D.W), with that of leaves (average 1105 % D.W). Generally, a threshold value of a minimum Ca requirement (5-6 mg Ca-1 100 g FW) from a mineral analysis of fruit at harvest is used to predict bitter pit levels (Johnson *et al*., 1987; Terblanche *et al*., 1980, Nielsen and Nielsen, 2003). Low Ca values have been associated with high risk of manifesting bitter pit (Ferguson and Watkins, 1989; Saure, 2005) and low Ca fruit concentration together with high N contents in fruits may increase the incidence of bitter pit development in fruits (Saure, 2005). According to Estanis *et al*. (2015) the analysis of Ca content in fruit does not always explain the incidence, or absence, of symptoms in a particular orchard. Ferguson and Watkins (1989) suggested Ca concentration (DW Basis) of 0.002% (flesh), as a minimum to avoid bitter pit (BP), the main physiological disorder due to Ca deficiency. In the case of this study Ca values reached levels below this threshold during the first year. In second year, the fruit Ca levels are over this limit (≥ 0.028% DW) and these results could explain in part the very low incidence of physiological disorders associated with Ca in the studied fruits. P fruit concentration in fruit (FW Basis) (average 11.1 mg 100 g^{-1} during the first and 13,8 mg 100 g^{-1} during the second year) reached values just above the limit of deficiency (7-9 mg 100 g^{-1}) (Nielsen and Nielsen, 2003). Low P fruit concentrations have been associated with the development of low-temperature breakdown in susceptible cultivars (Nielsen and Nielsen, 2003). According to Swietlik and Faust (1984), N/Ca ratios are more related to the development of bitter pit than Ca contents in fruit tissues alone. N/Ca ratios in the fruit were less than 30, which may be considered a threshold value for ensuring a good storability of fruit (Faust, 1980; Link, 1992; Fallahi *et al*., 1997). Different authors have emphasized the importance of K/Ca, Mg/Ca and K+Mg/Ca ratios for assessing fruit quality status (Piestrzeniewicz and Tomala, 2001; Bramlage, 1980).

In most of the cases, K/Ca ratios reached values over 28 during both years, which has been recommended in Poland (Piestrzeniewicz and Tomala, 2001) as a limit for ensuring a good fruit quality. During the first year values even exceed the value 30, which is considered by Drahorad and Aichner (2001) as a threshold for ensuring a high fruit quality in apples. Both years, K+Mg/Ca values were higher than the threshold of 12 suggested by Van der Boon (1980) as the limit to avoid physiological disorders like bitter pit in fruits. Therefore the high K+Mg/Ca and K/Ca ratio detected both years under the conditions of the present study seems to be a risk for the development of physiological disorders like bitter pit in the future. Regarding leaf mineral concentrations our results are comparable to those reported by Gasparatos *et al*. (2011), who compared effects of organic and conventional apple orchard management on plant mineral content which was not significantly affected by treatments.

Mineral values reflect normal levels for N, K and Mg, high levels of P and low levels for Ca (Weir and Creswell, 1991). The critical Ca threshold value in apple leaf is reported to be 1.0 % DW (Weir and Creswell, 1991). In all treatments, leaf Ca was slightly over this critical level. This can be explained by its very low mobility in the plant, implying naturally low uptake of Ca and storage as Ca pectate. High foliar P levels could be explained attending the adequate P Olsen P values (15 mg kg^{-1}) in the 0-20 cm layer. The absence of statistical differences between nutrient concentrations in leaves may be related to soil fertility, considering the high levels of organic matter (4.8%) and medium content of available N (21.0 mg kg^{-1}). Other factors that may have influenced these results are the favourable climatic and orchard management conditions. Probably more study seasons will be required to assess the effect of this parameter on apple trees.

Evidence of the occurrence of bitter pit was only detected after 60 days of storage in the case of the treatment with the highest dose of N, but in a very low level (1.1 in a scale 1-4). This occurrence did not constitute a significant difference. None of the treatments showed a occurrence of water core, internal breakdown, scald or diseases caused by pathogens although relatively small amounts of Ca was partitioned into fruits of the study. Some of the preharvest factors that may explain these favorable results are the adequate fruit N concentration, adequate crop load and fruit size (Ferguson and Watkins, 1989), adequate climatic and growth conditions (Johnson and Ridout, 1998) and storage conditions for the fruit (Dris *et al*, 1999) among others.

No variation between treatments was detected for branch cross-sectional area (BCSA) and seasonal shoot extension growth. The average seasonal shoot extension growth during the first year was 37.9 cm and 40.6 cm during the second.

5. Conclusions

Decreasing levels of organic N-fertilization did not influence tree cropping during the first (2009) and second year (2010) of the study. Probably long-term applications of decreasing organic N fertilizers will be required to assess the effect of this parameter on apple trees.

Fruits showed low Ca concentrations (2.8 to 3.3 mg Ca 100 g^{-1} FW), high levels of K (118.6 to 130.1 mg K 100 g^{-1} FW) and high values for K+Mg/Ca (> 12) and K/Ca (> 30) ratios. Mineral concentration on leaves was not affected by slight of organic N-fertilization (normal concentrations for macro and microelements). Occurrence of bitter pit was only detected after 60 days of storage in the case of the treatment with the highest dose of N. Based on these results we have to consider not only the orchard nitrogen management but also fruit mineral ratios and Ca foliar applications for managing fruit production and quality in organic apples affected by Bitter pit. Further studies should be carried out on different soils and apple varieties to test the effect of different doses of organic N amendments on fruit production and quality of organically cultivated apples.

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