



Minerals profile of two globe artichoke cultivars as affected by NPK fertilizer regimes



Sara Lombardo, Gaetano Pandino, Giovanni Mauromicale*

Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A), University of Catania, via Valdisavoia 5, 95123 Catania, Italy

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ABSTRACT

Globe artichoke is a proven source of various minerals (such as K, Fe and Zn) in the Mediterranean diet, but their content in response to fertilizer regime has not yet been investigated sufficiently. Thus, we monitored the effect of two contrasting nitrogen/phosphorus/potassium (NPK) fertilizer regimes (one balanced and the other excessive) on the minerals accumulation of 'Apollo' and 'Tema 2000' cultivars, grown in three Sicilian locations ('Landolina', 'Iannarello' and 'Zotto') - South Italy. Except for total nitrogen, the balanced fertilizer regime favoured the accumulation of both macro- and micro-minerals, but with a different extent depending especially on trial location. Particularly, plants grown at 'Iannarello' responded more strongly to the fertilizer regime with respect to K, P, Ca, Fe and Zn accumulation, as a result of its different soil characteristics than the other locations. Providing a balanced supply of nitrogen/phosphorus/potassium via fertilization can enhance the nutritive value of globe artichoke, but taking into account especially soil characteristics.

1. Introduction

The annual global production of globe artichoke [*Cynara cardunculus* var. *scolymus* (L.) Fiori] heads is about 1,6 million tons, mostly harvested in the Mediterranean Basin and in particular in Italy, where it is grown over some 46 Kha (FAO, 2014). However, recently a growing contribution from Americas and China was observed (FAO, 2014). The edible part of the plant is represented by the inner parts of the immature inflorescence (referred to variously as the "head" or "capitulum"), which account for nearly 35–55% of the whole head depending on the cultivar and harvest time (Bianco, 1990). The product is appreciated in both its fresh and processed forms (Baty-Julien & Hélias, 2012) and has been recognized as a source of various health-promoting substances, among which fiber, minerals, inulin and polyphenols (Pandino, Lombardo, Mauro, & Mauromicale, 2012; Pandino, Lombardo, Williamson, & Mauromicale, 2012). However, while polyphenols and inulin are not essential to life, minerals deficiencies are responsible for acute metabolic disorders and may compromise human health (Welch et al., 2009).

Although plant foods can serve as dietary sources of all essential minerals required by humans (Grusak, 2002), several factors may directly or indirectly affect the concentration and availability of minerals. Thus, efforts are underway to enhance the minerals content or bioavailability of existing levels in plant foods in an attempt to ensure adequate attainment of dietary minerals in all individuals (Grusak, 2002).

The minerals profile of globe artichoke head is known to depend heavily on the choice of cultivar and location (Pandino, Lombardo, & Mauromicale, 2011), but there is little understanding to date about the influence of crop management practices on the minerals accumulation. In particular, no literature data still exist on the impact of nitrogen/phosphorus/potassium (NPK) fertilizers application on the minerals profile in the edible fraction of globe artichoke. Indeed, globe artichoke is cultivated on a wide range of soil types (Elia & Conversa, 2007), many of which have low levels of N and P availability, but a moderate to high level of K (Ierna, Mauro, & Mauromicale, 2012). Hence, over recent decades growers usually provide the crop with massive doses of NPK fertilizer (Burt et al., 2009) in order to accelerate plant growth and maximize economic yields. This practice is increasingly recognized to be energy inefficient, non-sustainable and environmentally unsound (Burt et al., 2009; Erhart, Feichtinger, & Hart, 2007). Thus a more balanced fertilizer regime is currently more encouraged (Stefanelli, Goodwin, & Jones, 2010), also in order to satisfy a rising consumer demand for healthy foods and sustainable production. In addition, an our recent work (Lombardo, Pandino, & Mauromicale, 2015) highlighted that manipulating the application of NPK-based fertilizer may provide a convenient means of stimulating the accumulation of nutraceuticals in the globe artichoke head. Furthermore, we recently highlighted as fertilization has a significant influence on the overall quality of minimally processed globe artichoke heads (Lombardo et al., 2017). The impact, if any, of the fertilizer regime on

* Corresponding author.

E-mail address: g.mauromicale@unict.it (G. Mauromicale).

the minerals profile of the head has not been identified as yet. Thus, the objective of the present research was to evaluate the differential influence of two different NPK-based fertilizer regimes, one of which provided a balanced supply of the macronutrients and the other which provided an over-supply as commonly adopted by local growers, on the accumulation of macro- and micro-minerals in the head. To corroborate our experiments, three locations contrasting in soil type characteristics (but not in climate) were screened.

2. Materials and methods

2.1. Trial location description, experimental design and management practices

The field experiments were performed during the 2011–2012 growing season at three not greatly dispersed locations ('Landolina', 'Iannarello' and 'Zotto') in the Catania Plain, an area of Sicily (South Italy) where globe artichoke is widely cultivated. These locations were selected since they are contrast with respect to soil type, but are meteorologically very alike. Specific soil characteristics and meteorological conditions recorded during the field trials were discussed in our previous work (Lombardo et al., 2015). In particular, the 'Zotto' soil had the highest level of Ca, Na, Mn and Cu; while the 'Iannarello' soil displayed the highest amounts of K and Mg than the other two soils. The 'Landolina' soil contained the highest levels of Fe and Zn (Table 1).

At each location the experiment was designed as a split plot with four replications. The two NPK fertilizer regimes, representing the main plots, were: balanced regime (200 kg N, 180 kg K₂O and 200 kg P₂O₅ ha⁻¹), formulated to deliver an optimal ratio of macronutrients for the stimulation of crop growth, and excessive regime (500 kg N, 250 kg K₂O and 250 kg P₂O₅ ha⁻¹), reflecting common commercial usage in Sicily. 'Tema 2000' and 'Apollo' cultivars were treated as sub-plots and their morphological characteristics were already reported by Lombardo et al. (2015), as well as information about plant material and management practices adopted. In particular, fertilization with P and K was done prior to planting, incorporating into the top 20-cm soil layer the above-indicated levels of triple superphosphate (48% P₂O₅) and potassium sulphate (51% K₂O) for each regime. N was applied five times (every 55 days from late August until middle-March) by a liquid fertilizer (Nitro-plus34®) with a 34% of N concentration.

Table 1
Soil characteristics at the three trial locations tested.

Soil characteristics	Trial location		
	"Landolina"	"Iannarello"	"Zotto"
Clay (< 0.002 mm) (%)	29	27	27
Silt (0.02–0.002 mm) (%)	28	36	30
Sand (2–0.02 mm) (%)	43	37	43
Total N (g kg ⁻¹)	1.4	1.5	0.8
Organic matter (g kg ⁻¹)	44	31	27
P ₂ O ₅ available (ppm)	4.4	10.6	25.2
K ₂ O exchangeable (ppm)	550	1240	263
Total CaCO ₃ (%)	9.8	12.2	25.1
Active CaCO ₃ (%)	5.5	9.2	15.5
Electrical conductivity (µS cm ⁻¹)	287	1034	3309
pH	7.5	7.2	7.0
Cation exchange capacity (meq 100 g ⁻¹)	44	37	110
K (mg kg ⁻¹)	469	1017	235
Mg (mg kg ⁻¹)	744	1135	464
Ca (mg kg ⁻¹)	6980	4480	10,280
Na (mg kg ⁻¹)	368	713	851
Fe (mg kg ⁻¹)	202	90	83
Mn (mg kg ⁻¹)	36	30	41
Cu (mg kg ⁻¹)	12	7	15
Zn (mg kg ⁻¹)	9	4	4

2.2. Sampling procedure and preparation

In early-March, at least 10 disease-free whole heads per replicate were harvested at the usual marketing stage (Mauromicale & Ierna, 2000) and regardless of their size. At Catania University laboratories such heads were mixed, washed with tap water and dried with tissue paper. The edible fraction (receptacle), after the bracts had been manually removed, was weighed and diced. Finally, a portion was oven-dried at 65 °C (Binder, Milan, Italy), until a constant weight was reached, in order to determine the dry matter (DM) content. Then, the dehydrated material was ground and passed through a 1-mm sieve, and used for the following chemical analyses. All analyses were performed in triplicate.

2.3. Total N content and minerals profile determination

An amount (0.5 g) of dehydrated sample was directly used for total N determination by using Kjeldahl method (Nelson & Sommers, 1980) and the total N content in the samples was expressed as % of DM.

Nine minerals (P, K, Mg, Ca, Na, Fe, Mn, Zn and Cu) were also analyzed. Approximately 1 g of the oven-dried material was put in a muffle furnace at 550 ± 2 °C for 24 h. After cooling at room temperature in a desiccator, P was estimated according to the molybdo-vanadate colorimetric method 986.24 (AOAC, 1995) using a Shimadzu 1601 UV-Visible spectrometer (Shimadzu Corp., Tokyo, Japan), while the other minerals (*i.e.* Ca, Mg, K, Na, Cu, Fe, Zn and Mn) were analyzed by atomic absorption spectrometry adopting the AOAC (1995) method 975.03. A Perkin Elmer (Norwalk, USA) AAnalyst 200 atomic absorption spectrometer equipped with a multi-element hollow cathode lamp and a deuterium background correction system was used.

The quantification of each individual mineral in the sample was performed by its calibration curve (AOAC, 1995) and data were expressed as g or mg kg⁻¹ of DM.

All analyses were performed in triplicate. All the reagents and solvents were purchased from Sigma-Aldrich (Milan, Italy) and were of analytical grade. Bidistilled water was used throughout this research.

2.4. Statistical analysis

Levene's test was used to test for homoscedasticity, following which the data were subjected to a three-way analysis of variance (ANOVA), based on a factorial combination of two fertilization regimes × two cultivars × three locations. Means were separated by a least significance difference (LSD) test, when the *F*-test was significant. All calculations and analyses were performed using CoStat® version 6.003 (CoHort Software, Monterey, CA, USA).

3. Results and discussion

The globe artichoke edible fraction contains substantial amounts of certain minerals (such as K, Fe and Zn), whose concentration is known to be influenced by biotic and abiotic factors (Pandino et al., 2011), as observed in other crops (Lombardo, Pandino, & Mauromicale, 2013; Lombardo, Pandino, & Mauromicale, 2014; Rosborg, Gerhardsson, & Nihlgård, 2009). In the present study, the effects of fertilizer regime, trial location, cultivar and their interactions on the minerals profile in the globe artichoke edible fraction are presented in Tables 2–5.

3.1. Total N content

The fertilizer regime explained ~64% of the variance in total N content in the globe artichoke edible fraction, while its interaction with trial location accounted for a further 10.5% (Table 2). As expected, such parameter was higher under the excessive fertilizer regime than under the balanced ones (Table 3). This was especially evident at 'Landolina' and 'Iannarello' than at 'Zotto' (Table 4), confirming that soil fertility

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