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Morphological characterization, biomass and pharmaceutical compounds in Italian globe artichoke genotypes

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ABSTRACT

Globe artichoke [*Cynara cardunculus* var. *scolymus* (L.) Fiori] is a perennial herbaceous plant cultivated principally in the Mediterranean basin for its immature inflorescences (heads). Among the other possible uses of this species, biomass production may be considered. In this work, 17 Italian globe artichoke genotypes have been studied for two years in the field in order to evaluate their biomass production for pharmaceutical active compound extraction and to select the genotypes more suitable for this purpose. Biomass has been characterized agro-morphologically, using five of the UPOV (International Union for the Protection of New Varieties of Plants) descriptors (i.e. plant height, number of lateral shoots, floral stem diameter, first fully developed leaf length and leaf lobe number) along with other six traits explaining biomass production (i.e. lateral shoot number, first fully developed leaf width, main floral stem leaf number, dry leaf number, plant diameter and plant dry weight), and biochemically to determine by HPLC analysis the phenolic compound content. Genotypes were significantly different for many of the morphological and biochemical traits evaluated. The results indicated that globe artichoke dry biomass yield of some Italian spring genotypes is worth considering (9.7 t ha^{-1}, as average value of all genotypes evaluated in the two growing seasons). Chlorogenic acid (ranging from 0.22 g kg^{-1} DM to 27.85 g kg^{-1} DM) and 1,5-*O*-dicaffeoylquinic acid (ranging from 0.42 g kg^{-1} DM to 2.10 g kg^{-1} DM) were the main phenolic compound detected using HPLC analysis. Two genotypes were selected for high biomass and phenolic compound production. This may open new horizons to the industrial use of the crop, which could represent a potential for the increase of the farmers' income.

1. Introduction

Since ancient time, globe artichoke [*Cynara cardunculus* var. *scolymus* (L.) Fiori] has been used in traditional medicine for its recognized therapeutic effects such as hepatoprotective, anticarcinogenic, antioxidative, antibacterial, urinative, anticholesterol, glycaemia reduction (Saénz Rodriguez et al., 2002; Coinu et al., 2007; Rondanelli et al., 2011; Fantini et al., 2011) linked principally to the high content of polyphenolic compounds, which include mono- and di-caffeoylquinic acids and flavonoids (Fratianni et al., 2007; Lattanzio et al., 2009; Lombardo et al., 2010; Pandino et al., 2010, 2011a, 2011b, 2012, 2013; Negro et al., 2012). In particular, within the caffeoylquinic acid derivatives, chlorogenic acid is the most abundant component (Lattanzio et al., 2009). Also the flavonoids apigenin and luteolin and their glycosides have been widely described in globe artichoke (Lombardo et al., 2010; Pandino et al., 2010, 2011b, 2012, 2013; Negro et al., 2012). All these compounds have strong antioxidant properties and protect low density lipoproteins from oxidative damages (Lattanzio et al., 2009). In this regard, some studies have been done to analyze biochemically globe artichoke germplasm suitable principally for fresh consumption or/and industrial processing of the heads (Fratianni et al., 2007; Bonasia et al., 2010; Lombardo et al., 2010; Pandino et al., 2010, 2011a, 2011b). In the last years, other possible applications of globe artichoke, alternative to the traditional ones, were envisaged. Different types of products can be harvested and utilized to obtain: (i) oil from seeds (Foti et al., 1999); (ii) inulin from roots (Raccuia and Melilli, 2004, 2010); (iii) energy from biomass (Ierna and Mauromicale, 2010; Ierna et al., 2012; Ledda et al., 2013); (iv) fiber as potential reinforcement in polymer composites

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Table 1
Globe artichoke spring genotypes evaluated.

Genotypes	Type	Donor institute	Origin
S2	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
S3	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
S5	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
S11	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
S17	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
S18	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
Castellammare	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
S23	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
Campagnano	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
Grato 1	Romanesco	Enea (RM) – Tuscia University (VT)	Latium, Italy
Ascolano	Romanesco	CRA-ORA Monsampolo del Tronto (AP)	Marche, Italy
Jesino	Romanesco	CRA-ORA Monsampolo del Tronto (AP)	Marche, Italy
Montelupone A	Romanesco	CRA-ORA Monsampolo del Tronto (AP)	Marche, Italy
Montelupone B	Romanesco	CRA-ORA Monsampolo del Tronto (AP)	Marche, Italy
Bianco di Pertosa	Romanesco	CRA-ORT Pontecagnano (SA)	Campania, Italy
Tondo Rosso di Paestum	Romanesco	CRA-ORT Pontecagnano (SA)	Campania, Italy
Pisa	Violetto	Pisa University (PI)	Tuscany, Italy

RM, Rome; VT, Viterbo; AP, Ascoli Piceno; SA, Salerno; PI, Pisa.

(Fiore et al., 2011); (v) green forage for ruminant feeding (Fateh et al., 2009); and (vi) natural rennet for traditional cheese making (Llorente et al., 2004). Globe artichoke can also be used as crop for metal-accumulation (Hernández Allica et al., 2008). In general, these new possible uses of globe artichoke are related principally to the European Union research support on new agricultural by-products (industrial raw materials) and have led to an increasing interest in aboveground biomass of this species. This interest is due mainly to the great adaptation of the crop to Mediterranean climate, characterized by low annual rainfalls and hot dry summer, to the relatively low crop energy input and to the large biomass productivity (Angelini et al., 2009). Until now, several studies on globe artichoke as energy crop have been done (Ierna and Mauromicale, 2010; Ierna et al., 2012), but there are only few suggestions on the use of its biomass as raw industrial material to recover phenolic active compounds. In particular, not many data are available in the literature on the extraction from globe artichoke biomass of active biocompounds, which are of interest for the pharmaceutical industry. This interest could meet the increasing demand of natural antioxidants due both to health concerns, linked either to the present use of synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) or to consumers' preference (Llorach et al., 2002).

Therefore, in the present work, a sustainable production of globe artichoke biomass and biocompounds of interest for pharmaceutical industry have been evaluated and the possibility of using such biomass, without upsetting traditional agricultural practices, has been also considered to allow a possible increase of farmers' income. Taking into account these preliminary remarks, the present work aimed at: (i) establishing the most appropriate plant traits capable of describing globe artichoke plant biomass production; (ii) characterizing the aboveground biomass of Italian globe artichoke spring genotypes both under the morphological and biochemical profiles; and (iii) selecting the genotypes more suitable for this purpose.

2. Materials and methods

2.1. Experimental field and plant material

Seventeen Italian spring globe artichoke genotypes were considered in our study (Table 1). Field trials were conducted for two years, during the 2008–2009 and 2009–2010 growing seasons, at the experimental station of ARSIAL (Latium Regional Agency for the Development and the Innovation of Agriculture) in Cerveteri (41°59′ N 12°01′ E), Rome (Italy), in a sandy clay loam soil (USDA soil classification system, 1975). The soil characteristics were as follows: sand, 62%; clay, 23%; silt, 15%; pH 6.3; organic matter, 1.24%; total nitrogen, 0.08‰; P, 24 ppm; K, 355 ppm; CE 0.16 mS. All genotypes were vegetatively propagated by offshoots and assessed in a completely randomized block experimental design with three replications. The total area used for the experiment was about 0.20 ha. Each field plot (elementary unit area of 15.60 m^2) totally consisted of 20 plants (planting density of about 7700 plants ha^{-1}, inter and intra-row distances of 1.30 and 1.00 m, respectively). The transplanting date was 17 August 2008. Field experiments were conducted under low chemical inputs (minimized fertilization using N 100 kg ha^{-1}, P_2O_5 90 kg ha^{-1}, K_2O 125 kg ha^{-1} each year) for the crop agronomical management, taking into account the agronomic techniques traditionally used in the cultivation area of Central Italy. In the first year of the trial, one third of the nitrogen fertilizer was distributed as ammonium sulphate in autumn and two thirds as ammonium nitrate during the stem elongation phase. In the second year, half nitrogen was applied as ammonium sulphate at the plant sprouting stage in September and half as ammonium nitrate at the stem elongation stage. Weed control was performed manually three times during the first experimental year and twice during the second one. At the end of the first growing season (at the end of May), stalk removal operation has been performed manually. No evident crop diseases were detected. The crop was irrigated with 50 mm of water only twice per year, using the drip irrigation system.

During the two-year experimental trials, daily temperature and rainfall were measured by a meteorological station in the experimental field. The collected data are shown in Fig. 1.

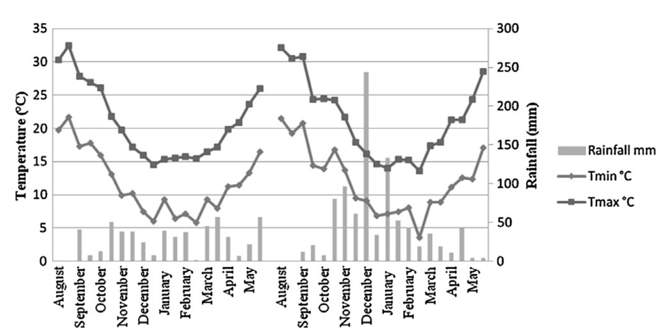

Fig. 1. Rainfall and air temperature during the experimental growing seasons at Cerveteri experimental field station. Data reported are the temperature mean or the cumulative rainfall amount of 15 days.