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EFFECT OF CROP MANAGEMENT PRACTICES ON GLOBE ARTICHOKE PHYSIOLOGICAL, NUTRITIONAL, AND NUTRACEUTICAL QUALITY

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1. INTRODUCTION

The globe artichoke (*Cynara cardunculus* L. var. *scolymus* (L.) Fiori) is an important herbaceous perennial species native to the Mediterranean Basin cultivated predominantly in Southern European regions which hold the 40% of world production. It is also cultivated in the North Africa (32.4%) following USA and South America (17.7%), and in the Far East (9.8%), specifically China with a production in a significant increase (FAO, 2022: http://faostat.fao.org/). European crop cultivation is extended on 57.8 ML of ha with the main producer countries represented by Italy (38 Kha), followed by Spain (13.7 Kha), France (4.6 Kha), and Greek (1.0 Kha). The species contributes significantly to European farmers economic profitability thanks to earliest heads production characterized by higher quality and commercial price (Mauromicale, 1987; Mauromicale, 1988; Mauromicale *et al.*, 2004), 2004) representing a traditional ingredient of Mediterranean diet (Ceccarelli *et al.*, 2010). Indeed, the autumn-winter production is normally destined to the fresh consumption, while that harvested during the spring period is used by the processing industry (Del Nobile *et al.*, 2009). Furthermore, starting from globe artichoke plants can be extracted industrial by-products used as food additives, nutraceuticals (Lattanzio *et al.*, 2009; Ceccarelli *et al.*, 2010) or for pharmacological use (Salem *et al.*, 2015). In Italy, globe artichoke cultivation is limited to Southern Regions such as Apulia, Sicily, and Sardinia. This vegetable in the past was widely widespread in the Sardinian horticultural systems extending over the area of 12.899 ha in 2016 (ISTAT, 2022) and representing an important driving force of the island's economy (Pisanu *et al.*, 2009). Recently, the reduction of surface cultivated recorded is equal to -47.12% from 2017 to date (ISTAT, 2022). This decrease is related to several factors including the reduction of globe artichoke productivity due to the lack of quality of propagation material, the increased labour cost, and technical means (Pisanu *et al.*, 2009), and the increased competitiveness of other producing countries such as Egypt. Improving the competitiveness of these cropping systems implies a change in the current production system to improve the quality of head and differentiate it in the globalized market. In recent decades, consumers are more interested in food quality, with particular attention to their positive impacts on human health with a preference for organic food or products obtained with sustainable methods (Willer and Lernoud, 2017, 2019). To date, the economic value of the globe artichoke is associated with head consumption as a source of antioxidants, in that considered a functional food because of its high level of bioactive metabolites, such as polyphenols and flavonoids (Lattanzio *et al.*, 2009; Ceccarelli *et al.*, 2010; Lombardo *et al.*, 2010, 2012; Dabbou *et al.*, 2016). Indeed, globe artichoke heads are especially high in caffeoylquinic acid derivatives contents (Pandino *et al.*, 2013), such as chlorogenic acid (Schütz *et al.*, 2004) apigenin, lutein (Romani *et al.*, 2006; Pandino *et al.*, 2013) and different cyaniding caffeoylglucoside derivates

(Wang *et al.*, 2003; Schütz *et al.*, 2004; Yoo *et al.*, 2012). These latter compounds are studied for their protective effect in relation to human health and against oxidative stress (Racchi *et al.*, 2002). Nevertheless, our knowledge, how sustainable management practices impact on growth, head quality and soil health of field-grown globe artichoke are poorly known. Scientific evidence indicates that sustainable management practices provide different beneficial effects over conventional cultivation such as on average higher levels of productivity (Lesur-Dumoulin *et al.*, 2017), improve soil organic matter and carbon stock especially in a soil to which fresh organic residues are added regularly (Shepherd *et al.*, 2002), and contributes positively to agro-biodiversity (Mondelaers *et al.*, 2009). Regarding the quality of vegetables, a study conducted by (Worthington, 2001) in organic crops showed high content in term of vitamin C, iron, magnesium, and phosphorus with significantly fewer nitrates than conventional crops while other authors showed indicate no differences in terms of microbial quality between organic and conventional vegetables (Maffei *et al.*, 2013) or nutraceutical compound such as flavonoids and polyphenols (Søltoft *et al.*, 2010).

Therefore, the link between products obtained through the adoption of sustainable agriculture and their high nutritional and nutraceutical potential remains uncertain and depends on different variables such as management cropping system (fertilization and weed control) (Roose *et al.*, 2010; Heimler *et al.*, 2017), genetic factors but also by soil and climate factors (Röhlig and Engel, 2010).

As regards globe artichoke Spinoso sardo varietal type, little information is available in the literature on the effects of sustainable agriculture versus conventional agronomic practices on nutrient and nutraceutical composition. The purpose of this study was to gain insight into the effects that alternative farming based on an agroecological approach *vs* conventional one has on globe artichoke production and quality. The heads productivity and quality under these management systems during three growing seasons were observed by evaluating yield components, heads physiology and composition in terms of total antioxidant activity of the heads over the course of different storage regimes and shelf-life.

2. MATERIALS AND METHODS

2.1 Site description and management systems

The experimental trial was established in Northern Sardinia at the "Sarciofo" private farm located in Uri, few kilometres apart from Sassari, in a typical district for the globe artichoke cultivation called Coros (40° N, 8° E; 128 m a.s.l.).

The experimental field was set up in 2018 as a part of the CarBio project (http://p-arch.it/handle/11050/1446) for three consecutive growing seasons to evaluate the effect of two different crop management systems on crop yield and quality parameters of globe artichoke heads.

The climate of the study site is Mediterranean defined by temperate rainy winter and warm summers with a 4-month drought period from May to August coinciding with the highest temperatures (Seager *et al.*, 2019). The average 30-year annual precipitation is around 715 mm with the highest frequency in the autumn and winter seasons (October to January). During the studied period (2018–2021), the main climatic parameters such as precipitation, maximum and minimum daily temperatures were recorded by a weather station located close to the experimental field. The mean minimum and maximum temperature in the 3-years ranged between 8-10 °C in January and 26-30 °C in August.

The study area is classified as alluvial origin (Haplic Luvisols and Gleyic Luvisols; Schad, 2016), flat to moderately hilly with the following main physical and chemical soil properties in the top 40 cm depth: clay-loam texture with a 55.0% sand, 28.2% silt, and 16.8% clay, pH 8.1, total nitrogen content 1.20 g kg^{-1} and soil organic matter content 1.6%.

The entire private farm was cultivated with globe artichoke (*Cynara cardunculus* L. var. *scolymus* L.) of the re-flowering Italian commercial varietal type Spinoso sardo following the traditional forcing technique as described in (Ledda *et al.*, 2013). Specifically, seedbed was prepared in June by ploughing at 35 cm, and sowing was carried out at the beginning of July for each growing season placing the semi-dormant offshoots at 3-7 cm depth. Plants were spaced 1.5 m between rows and 0.57 m within rows achieving a density of around 11969 plants ha^{-1}.

Two different management systems were compared: the ordinary practice of local farmers or conventional management (CONV) and an alternative management system (ALT).

The CONV management includes a continuous globe artichoke monoculture with the addition of chemical fertilizer to provide appropriate nutrient availability for crop. Specifically, fertilizers doses were supplied by considering characteristics of the soil, determined by soil analysis, and crop nutrient requirements calculated by (Piras, 2013) for Spinoso sardo. The dose of phosphorous and potassium distributed in pre-sowing was 170 kg ha^{-1} and 250 kg ha^{-1}, respectively, while nitrogen fertilization (equal to 190 kg ha^{-1}) was provided in two split events. The first was distributed when leaves covered 10% of ground (31 BBCH scale; Archontoulis *et al.*, 2010) and the second after the harvest of the first capitulum. In CONV system crop residues were incorporated at the end of the crop cycle (in June) at dry stage (Cadinu *et al.*, 2009; Pisanu *et al.*, 2009; Spanu *et al.*, 2018). Pest and disease controls followed the regional recommendations and weed control was achieved by mechanical means using the cultivator.

A surface of 2 ha in the “Sarciofo” farm was converted, at the beginning of the CarBio project, to alternative management practices (ALT). Specifically, in agreement with the farmer, the cultivation of the globe artichoke system was designed and managed consistently with agroecological principles adopting organic and integrate farming practices (Deligios *et al.*, 2017). This approach has involved cover crop introduction, biological disease control by mycoparasites utilization and the adoption of integrated weed management techniques. In ALT management globe artichoke was cultivated in monoculture with planting in July after ploughing in the middle of June. No mineral fertilization was distributed except for the first year of conversion (2018-2019) in which doses and time of fertilization was the same as CONV management. The cover crop introduced was a leguminous species: *Pisum sativum* L. var. Enduro (SIS Società Italiana Sementi) sowed in September in the interrow spaces. Legume cover crops have a positive influence on artichoke yield as a result of nitrogen storage, which is decomposed by microbial activity and released in plant available form to the next artichoke cycle, stabilizing nutrient fluxes in the long-term (Deligios *et al.*, 2017). In addition, residues of cover crops and globe artichoke chopped, ploughed, and soil incorporated at the end of the primary crop marketable period in mid-April at the fresh stage may contribute to weed suppression and soil seed bank reduction thanks to allelopathic activity of sesquiterpene lactones products of *C. cardunculus* L. (Scavo *et al.*, 2019). The two management systems in comparison were separated by 50 m distance to avoid interaction effects and possible cross-contamination.

2.2 Globe artichoke yield and nutrient balance

Heads biometric characterization and marketable yields were measured at the harvesting stage in all growing seasons. Specifically, globe artichoke harvest was conducted between November and April collecting representative heads samples of the primary, secondary, and tertiary orders. A total of 25 heads per management and order were measured when head their diameter higher than 7 cm. The average yield per plant was multiplied by crop density for absolute yield estimation.

Field gross nutrient balances for both management systems were calculated following the methodology proposed by OECD (2007a, b) and (Andrist-Rangel *et al.*, 2007). For estimation balance of N, P, and K, input and output data of both management systems were required. As input mineral fertilizers concentration distributed yearly as declared by the manufacturers (kg ha^{-1}), biologically N fixation of the cover crop (only ALT management system), and the annual atmospheric deposition rates calculated according to (Markaki *et al.*, 2010) for N and P. Nitrogen derived from atmosphere (Ndfa) according to the 15N isotopic dilution method (Warembourg, 1993) calculated by multiplying the pea N yields by %Ndfa index. The samples of cover crop aboveground biomass were collected in April with a random sampling (4 replicates) on a plot of 0.5 m^2 immediately before incorporation into the soil. Input of K included only that applied by fertilization, because the literature estimates are very few and not reliable the deposition atmospheric (Nastos *et al.*, 2007; Morselli *et al.*, 2008). The output data of the balance were calculated by multiplying the harvest yield of artichoke heads (kg ha^{-1}) by its nutrient content (OECD, 2007a, b).

Total N concentration in the artichoke samples was measured by dry combustion in an elemental analyzer LECO 628 (628 Series; LECO Corp., St. Joseph, MI, USA). Phosphorus and potassium were determined according to AOAC methods (1995). The results of gross balance are expressed on a per-year basis. Gross balance can be either positive, indicating a nutrient accumulation in the soil, or negative, indicating a nutrient depletion from the soil.

2.3. Plant materials and experimental design

To evaluate the effect of two different crop management systems on physiological, nutritional, and nutraceutical parameters quality of head of the globe artichoke, a preliminary test to gain information on physiology activity of globe artichoke was performed. Heads of globe artichoke varietal type Spinoso sardo were collected from both management systems compared (CONV and ALT) according to a randomized block design with three replicates. The quality components were determined after a formal soil conversion period valued in two years for horticultural systems to conform to the alternative management standard. The sampling was conducted monthly at marketable harvest stage (59 BBCH scale) starting from November to March. Immediately, within 1 hour from harvest, heads of globe artichoke were transferred to the laboratory of ISPA-CNR research station (Regione Baldinca, Li Punti, Sassari, Italy) under cooling condition in carton box to keep the temperature under 10 °C.

2.3.1. Physiology activity

Physiology activity rates were determined in 6 globe artichoke heads collected from both management systems studied. The measurements on the same artichoke heads were taken daily for 7 days at two different temperatures. Specifically, one refrigeration temperature at 5° C and another one at 20° C to simulate room temperature conditions were studied. Harvest artichoke heads occurred during the entire growing cycle of 2020-2021 starting from November until April with monthly sampling intervals. Preliminary, heads have been deprived of the stem and were placed individually in 1 L jars, whose lids were fitted with two silicon septa and closed for 4 h. Heads artichoke were stored at 1° C and for 2 h prior to CO_2 flux determination. O_2 and CO_2 concentrations were determined by a combined CO_2/O_2 analyser (Combi Check 9800-1, PBI-Dansensor A/S, Rinsted, Denmarck) and at sampling time the headspace air was mixed for 1 min by an electrical fan fixed inside the jar according to Palma *et al.*, (2018) methodology. The Combi Check analyser was connected with each jar by two tubes, each one ending with a needle inserted in one of the two septa, in order to form a closed system. Respiration activity, as release of CO_2, was expressed as ml kg^{-1} h^{-1}.

2.3.2. Chemical and reagents

Reagents and solvent such as: acetonitrile, trifluoroacetic acid, sodium carbonate and methanol were purchase from Merck (Darmstadt, Germany) and were of high-performance liquid chromatography grade. 2,2-diphenyl-1-picrydazyl (DPPH), Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), flavonoids, organic acids standard and Folin–Ciocalteu phenol reagent were from Fluka (Buchs, Switzerland). Cyanidin 3-rutinoside, Apigenin glucoside and quercetin 3-glucoside were purchased from Extrasynthese (Genay, France). Ascorbic acid, glucose, fructose, and sucrose were acquired from Sigma-Aldrich Co. (Milan, Italy).

2.3.3. Sample preparation and chemical determination

Chemical analysis of the samples of the artichoke was conducted on at least six disease-free edible heads per replicate (a total of 3 replicates) collected from the two management systems, harvested at the marketable size and prior to maturity and regardless of their size. Once harvested, heads have been deprived of stalks and the apical part with the long and sharp spines have been chopped. Each head was mixed, washed, and dried with tissue paper. The receptacle (edible fraction) after the bracts has been manually removed, sliced into four parts and a small portion was immediately taken from each part in order to have a sample for analysis of about 25 grams. The extraction of the nutritional components for analysis was carried out using a 50 ml of extraction solution prepared with methanol/water (80:20 v/v at 25° C temperature). The receptacles were placed in contact with 50 ml of extracting solution and homogenized using an immersion blender (model RCSM-350-400P, Royal Catering, Italy). Subsequently, the sample were shaken for 30 minutes in dark conditions at room temperature and the suspension was centrifuged for 15 min at 13.000 × g

(Centurion Scientific Ltd, West Sussex, England) and the supernatant was filtered through a 0.45 mm of acetate cellulose filter. The methanolic extracts were used for the assessment of different chemical parameters.

Carbohydrate and sweetness index

Analysis of soluble carbohydrates was performed by chromatographic analysis according to (Palma *et al.*, 2018) methodology. This method is based on enzymatic hydrolysis of oligofructose by fructanase, followed by spectrophotometric determination. The HPLC system (LaChrom Merck-Hitachi liquid chromatograph, Hitachi Ltd., Tokyo, Japan) consisted of a D-7000 system manager, L-7100 pump, and L-7200 auto-sampler was employed. For carbohydrates analysis, the HPLC system was coupled with an evaporative light-scattering detector (ELSD Sedex 60LT, Alfortville, France), and a Bio-Rad Aminex fast carbohydrate lead resin ionic form column (100 × 7.8 i.d.) with a Bio-Rad Carbo-P micro-guard cartridge thermostated at 80 °C. Isocratic mobile phase was prepared in ultrapure water with a flow rate of 0.8 mL min^{-1}. The ELSD detector was set as follows: drift tube temperature 45 °C; nebulizer gas (air) pressure: 2.5 bar. Stock standard solutions of each carbohydrate were prepared in ultrapure water and the carbohydrate concentration in samples was calculated according to the linear calibration curves of the standard compounds. The sweetness index of the artichoke heads was estimated of perception of total sweetness of the individual sugars. Specifically, was calculated on the basis of the amount and sweetness properties of the individual carbohydrates in the heads (Keutgen and Pawelzik, 2007). Since sucrose is 1.35 times sweeter than glucose and fructose is 2.3 times sweeter than glucose, (Qian *et al.*, 2004) the sweetness index was therefore calculated as:

$$(1.00\ [glucose]) + (2.30[fructose]) + (1.35[sucrose])$$

All data presented were expressed as g $100g^{-1}$ of fresh matter, FM.

Fiber content

The analysis of fiber using the Van Soest *et al.*, (1991) dividing the fraction in fiber in neutral detergent - NFD, fiber in acid detergent - ADF, and lignin in acid detergent - ADL. Preliminary, capitulum were dehydrated by freeze and reduced to a fine grind using ceramic ball mills.

Total Phenolic Content

The total phenolic content was determined according to the colorimetric method using the Folin-Ciocalteu reagent and based on the reduction of the a phospho wolframate-phosphomolybdate complex to blue reaction products (Singleton and Rossi, 1965) expressing the concentrations in mg g^{-1} of Gallic acid equivalents (GAE) of dry weight. For determination a standard curve was plotted using different concentrations of Gallic acid based on standard calibration curve. The mixture previously centrifuged was mixed with Folin-Ciocalteu reagent and allowed to react at room temperature. Sodium carbonate was added and put in a temperature bath at 30 °C. Then the tubes were rapidly cooled at the absorbance of 760 nm by a UV–vis spectrophotometer (Varian Cary 50, Netherlands). Antioxidant activity was assessed using the free radical DPPH (2,2-diphenyl-1-picrylhydrazyl) (Bondet *et al.*, 1997). The mixture containing 3 mL of a methanol solution of 0.16 mM DPPH and 100 mL extract of sample, was allowed to react for 15 min in a cuvette. The absorbance of the DPPH solution was determined at 515 nm by a UV–vis spectrophotometer. The percentage inhibition of the absorbance of DPPH solution added with sample was calculated using the following equation

$$Inhibition\,\% = \frac{(Abst\ = 0\ - Abst\ = 15\,min)}{Abst\ =\ 0\ \times 100}$$

Antioxidant activity was expressed as mmoles kg^{-1} of Trolox equivalent antioxidant capacity (TEAC).

Phenolic Compounds

The quali-quantitative characterization of phenolic compounds was carried out by chromatographic analysis following Palma *et al.*, (2018) methodology. In this thesis, the phenolic compound was separated using HPLC and identified by their retention times in comparison with commercially available standards, their UV/Vis spectra, and available data in the literature. For quantification and identification of phenolics compounds, the HPLC system (Hitachi Ltd., Tokyo, Japan) coupled with a L-7455 photodiode detector (DAD) and a C18 Prevail column (250 mm x.4.6 mm, 5 µm, Alltech, Milan, Italy), with an Alltech C18 precolumn (7.5 mm × 4.6 mm I.D.). HPLC elution was carried out at 30 °C using an elution profile with varying proportion of solvent A (H_2O with 0.1% trifluoroacetic acid) and solvent B (CH_3CN with 0.1% trifluoroacetic acid). The experimental plan included: an initial condition of 5% B; at 60 min, 25% B; at 70 min, 5% B; with a flow rate of 1 mL min^{-1}. The chromatogram was monitored simultaneously at 280 and 330 nm. Calculation of concentrations for Chlorogenic acid and apigenin-glucoside was based on external standards while the concentration of the other compounds was expressed as chlorogenic acid. Phenolic compounds were identified by LC-electrospray ionization (ESI) MS analysis using Agilent Technologies (Palo

Alto, CA, USA) 1100 series LC/MSD equipped with a diode-array detector (DAD). A chemstation HP A.10.02 was used for data analysis. All peak areas and retention times were expressed relative to the internal standard of hesperetin added prior to extraction of samples. All data were expressed as g kg^{-1} of DM.

2.3.4. Statistical analysis

Analysis of variance was performed to evaluate the influence of growing season and cropping system on heads of the three orders number and weight, heads production and their interaction. All raw data were checked for normality of distribution using the Kolmogorov–Smirnov test prior to statistical analysis. Data were analyzed with the SAS MIXED (SAS, 1996) procedure with cropping system considered as fixed effect, and growing season, replicates and their interactions considered as random effects. Means were separated by Tukey's honest significant difference test. All differences were considered significant at the 0.05 probability level.

Statistical analysis of quality parameters was performed using Statgraphics Centurion software (Herndon, VA, USA), version XV Professional statistical program. Analysis of variance (ANOVA) was carried out according to a single-factor design with three replications for each treatment, after testing (Skewness and Kurtosis) data normality assumptions. Mean comparisons were performed using Duncan's multiple range test at $P \leq 0.05$.

3. RESULT AND DISCUSSION

3.1. Heads yield production and heads order

As regard the effect of growing season on heads order, artichoke grown under the growing season III showed higher 2nd and 3rd heads order weight (tab. 1). By contrast, 1st heads order weight was insensitive to growing season and significantly affected by management system. In particular, the alternative management system ALT had a higher 1st heads order weight than the conventional one.

Table 1 Effect of growing season (I, II, and III) and management system (CONV and ALT) on heads yield production (kg ha^{-1}) and heads weight and number (1st, 2nd and 3rd order).

Factors	1st order heads		2nd order heads		3rd order heads		Heads yield (kg ha^{-1})
	Weight (g head^{-1})	Number (n. ha^{-1})	Weight (g head^{-1})	Number (n. ha^{-1})	Weight (g head^{-1})	Number (n. ha^{-1})	
Growing season							
I	24.1	11286	21.8 c	42105	19.9 b	43918	1171.0
II	22.5	10585	32.6 b	24269	17.6 b	34854	930.9
III	28.1	9971	35.6 a	23567	33.5 a	17690	969.5
Management system							
ALT	29.6 a	11013	29.0	31657	24.5	33879	947.0
CONV	20.2 b	10214	31.1	28304	22.8	30429	1100.5
P-values							
Growing season (G)	0.435	<.001	0.002	<.001	0.002	<.001	<.001
Management system (M)	0.021	<.001	0.463	<.001	0.582	<.001	<.001
G × M	0.148	<.001	0.309	<.001	0.328	<.001	<.001

For each parameter (growing season, and cropping system), within each column, means followed by different letters are significantly different according to Tukey's test (P ≤0.05).

Growing season and management system statistically affected the total number of heads (1st, 2nd, and 3rd order) being highly significant the growing season × management system interaction (tab. 1 and fig. 1). Also heads production was significantly affected by the growing season × management system interaction, where heads production was higher in ALT treatment in each growing season (tab. 1 and fig. 2).

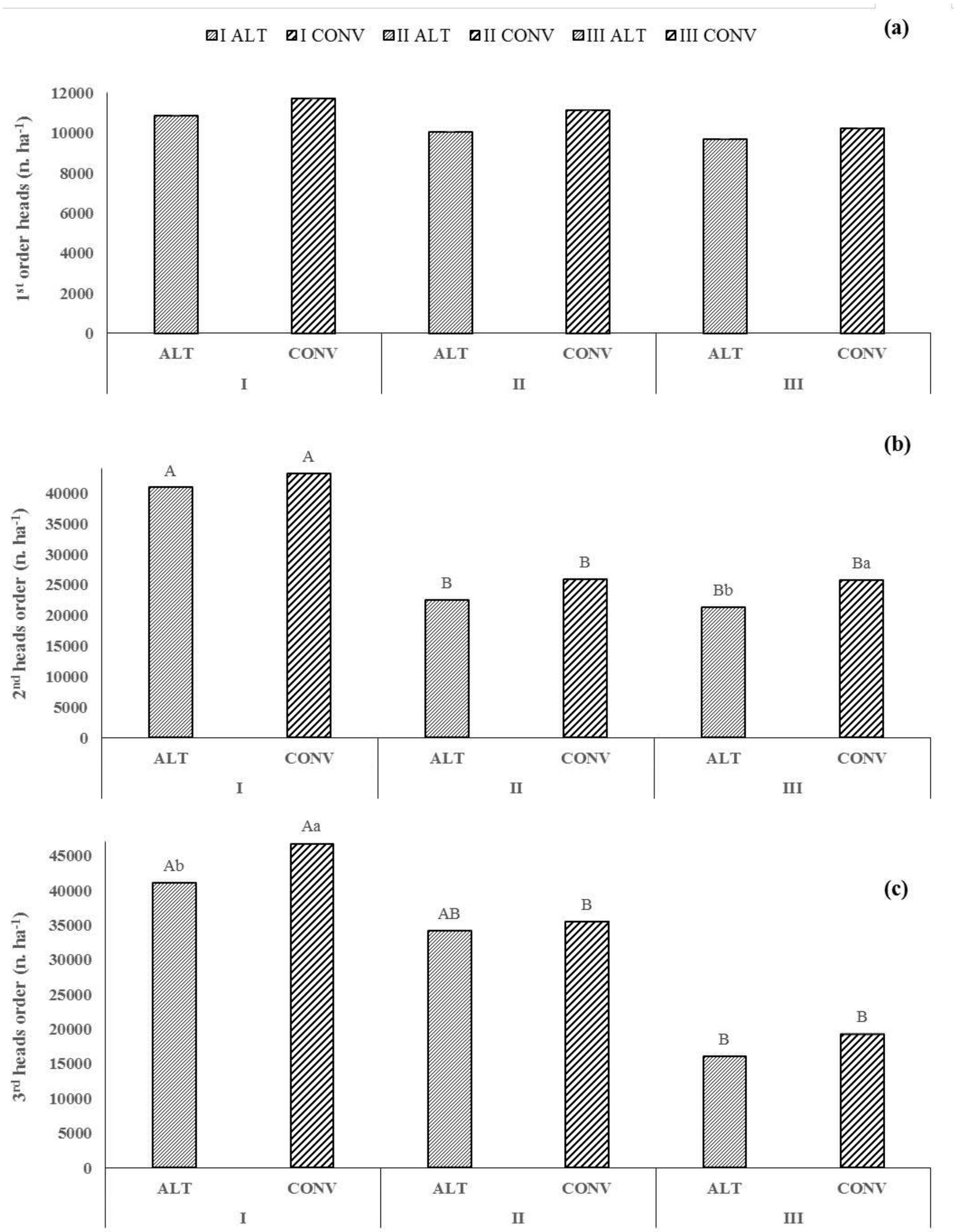

Figure 1 First (a), second (b) and third (c) heads order number affected by growing season × management system interaction. Different lowercase letters indicate significant differences within the same growing season and between management systems ($P < 0.05$), different uppercase letters indicate significant differences among growing seasons within the same management system ($P < 0.05$) according to the Tukey's test (Number of replicates = 3)

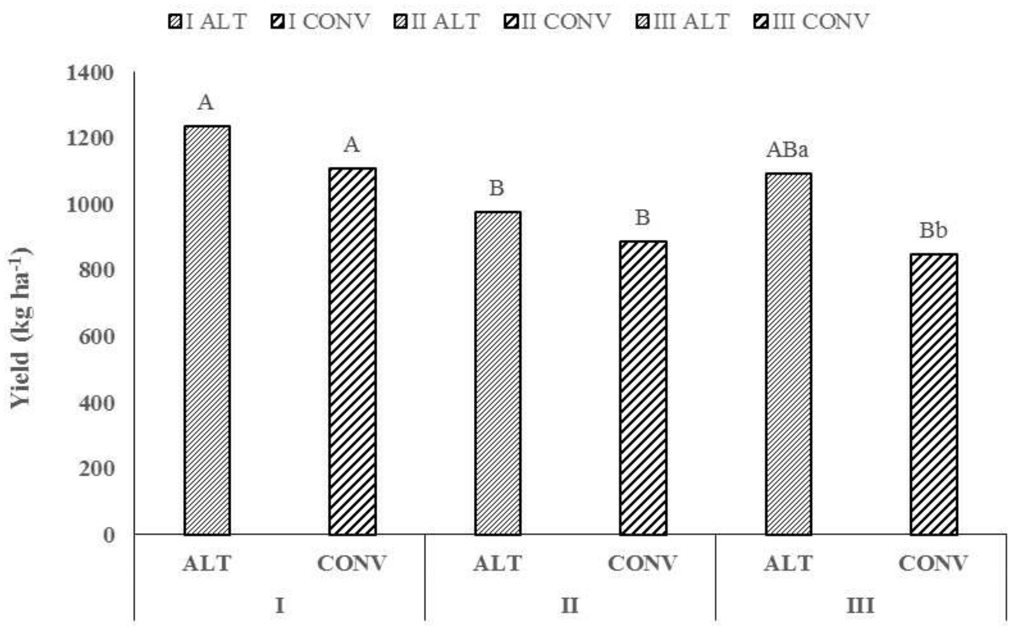

Figure 2 Heads yield production affected by growing season × management system interaction. Different lowercase letters indicate significant differences within the same growing season and between management systems ($P < 0.05$), different uppercase letters indicate significant differences among growing seasons within the same management system ($P < 0.05$) according to the Tukey's test (Number of replicates = 3).

The lack of differences in yield between management systems within the first and the second growing season suggests that the differences among growing seasons might be linked to meteorological trends occurred during the II growing season. Variation in summer (from planting to flower induction in the last 10 days of September) maximum temperature could be responsible for major yield fluctuations across years. Specifically, in the second growing season with the lowest yields (fig. 2), the maximum temperature was 1.5 °C (average from July to September) higher than the long-term weather series. By contrast, the relatively high yield across the two management systems (fig. 2) in the first growing season (I) was related to the highest average maximum temperature in winter months (+ 1.5 °C) and with no frosts. Similarly, in a short-term experiment, Ledda *et al.*, (2003) ascribed the high temporal variability of artichoke yields to the average maximum temperature encountered during the flower induction period. However, for a zucchini crop, although the variability of weather conditions between years may have affected total and marketable yields, cover crop management and organic fertilizers also caused significant effects (Montemurro *et al.*, 2013).

In the case of III growing season, statistically significant differences were observed between the management systems with higher artichoke heads yield in the ALT management compared to the CONV one (+22.4%). This trend across managements and over the growing seasons, that recorded heads yield similar to the first growing season (I), can be explained with the positive effects of ALT management. Specifically, the cover crop combined with fresh crop residue soil incorporation in ALT management has improved soil quality over time. This synergistic effect affected the amount of N release in the mineralization process which could potentially uptake of globe artichoke increasing heads yield. This phenomenon was confirmed by Kumar and Goh, (2002) that showed an increase in wheat yields following the incorporation of leguminous crop residues due to the effect of greater mobilization of N. Our results demonstrated that in globe artichoke when weather conditions during the development of heads were similar to historical weather trends, productivity was relatively stable. Indeed, when the maximum temperature during the summer months (negative influence) or during the winter months (positive influence) greatly exceeded the long-term maximum temperature values, we observed that globe artichoke production was dependent primarily on weather conditions rather than the management of the crop. Furthermore, the increase of crop yields observed in ALT management in the 2020-21 confirmed the capacity of the alternative system, based on agroecological principles approach, to support the soil fertility and crop productivity when compared to the CONV system, and to contrast yield losses in the short period.

3.2. Macronutrient balance

Because of the significant interactions between growing season and management system for all the analyzed macronutrients (tab. 2), data were reanalyzed by growing season (Figg. 3-5).

Table 1 Effect of growing season (I, II, and III) and management system (CONV and ALT) on nitrogen, phosphorus and potassium amount (kg ha^{-1}).

Factors	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**
Growing season			
I	144.0	147.6	162.3
II	50.3	70.6	85.4
III	57.6	72.1	94.4
Management system			
ALT	88.5	49.4	29.5
CONV	79.4	133.8	133.4
P-values			
Growing season (G)	<.001	<.001	<.001
Management system (M)	0.423	<.001	<.001
G × M	<.001	<.001	<.001

For each parameter (growing season, and management system), within each column, means followed by different letters are significantly different according to Tukey's test (P ≤0.05).

In the alternative system ALT, the annual gross N balance (and that for P and K) was relatively consistent over the years and was positive for all the analyzed growing seasons (Figg. 3-5) with an average surplus of 88.5 kg N ha^{-1} (ranging from 218 to 30 kg ha^{-1}). Significant differences were also detected in mean P and K surpluses (Figg. 4-5) among years (in the ranges of 164 –7 and 186 – 46 kg ha^{-1} for P and K, respectively).

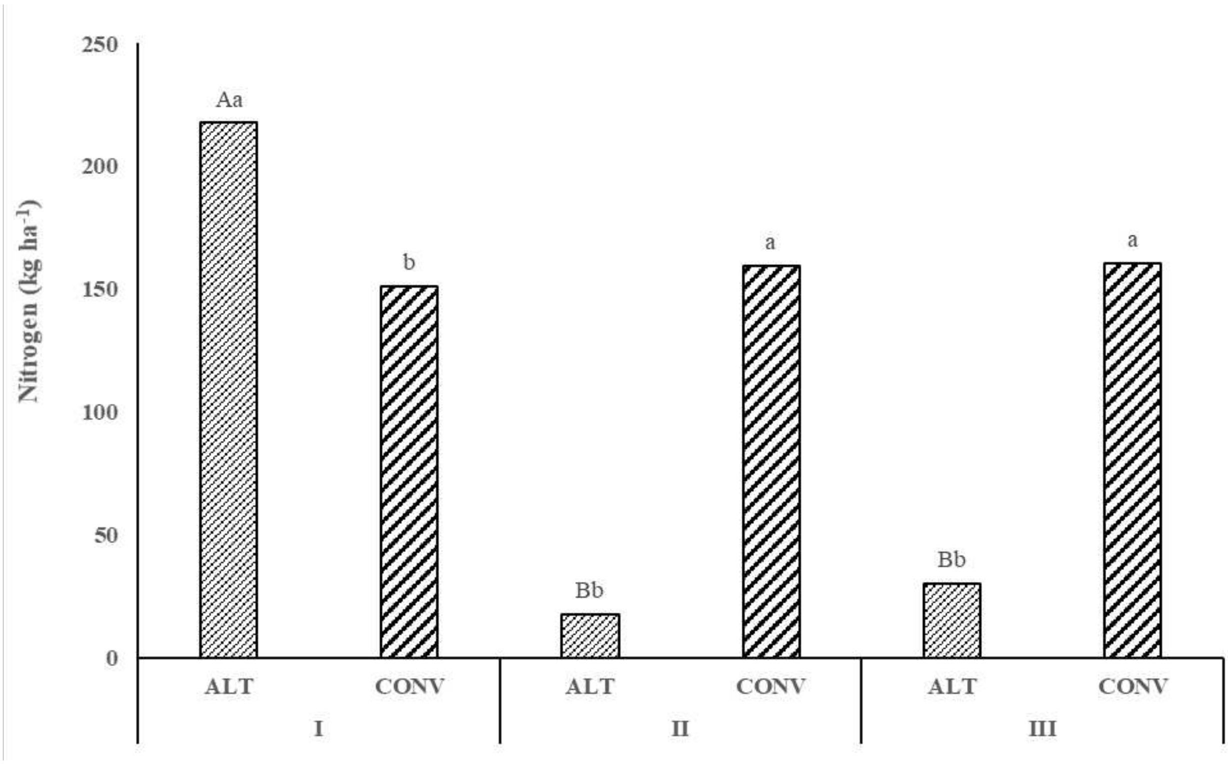

Figure 3 Nitrogen amount affected by growing season × management system interaction. Different lowercase letters indicate significant differences within the same growing season and between management systems ($P < 0.05$), different uppercase letters indicate significant differences among growing season within the same management system ($P < 0.05$) according to the Tukey's test (Number of replicates = 3).

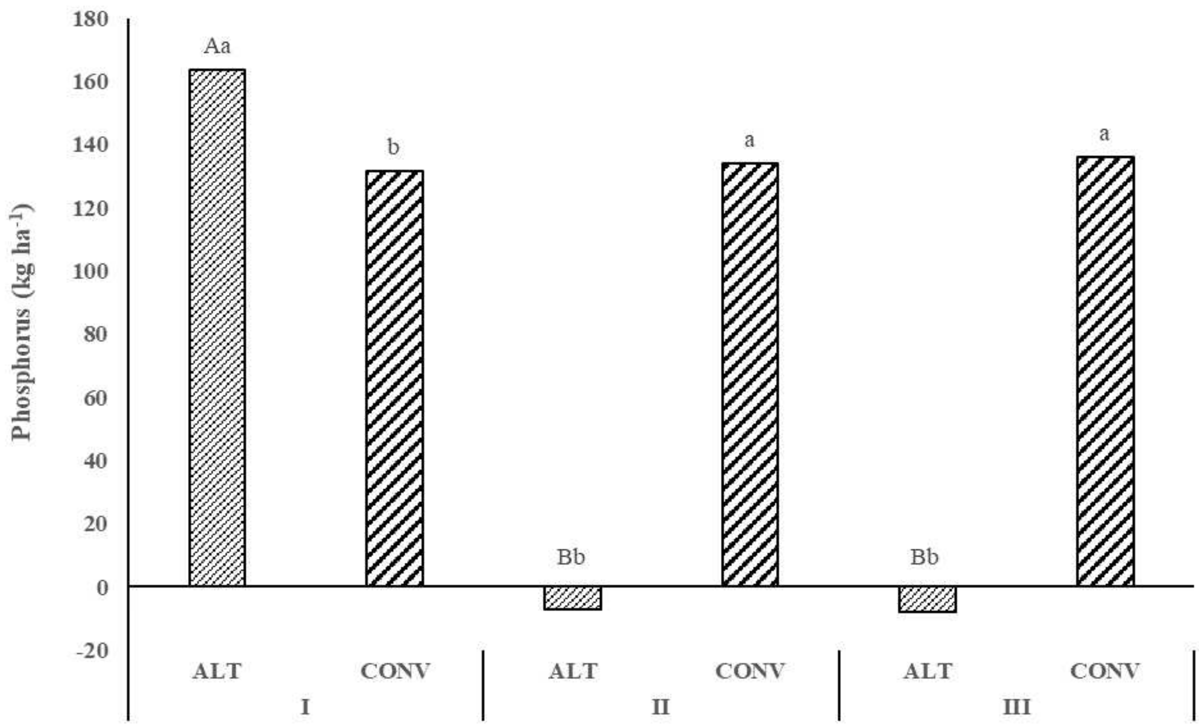

Figure 4 Phosphorus amount affected by growing season × management system interaction. Different lowercase letters indicate significant differences within the same growing season and between management systems ($P < 0.05$), different uppercase letters indicate significant differences among growing season within the same management system ($P < 0.05$) according to the Tukey's test (Number of replicates = 3).

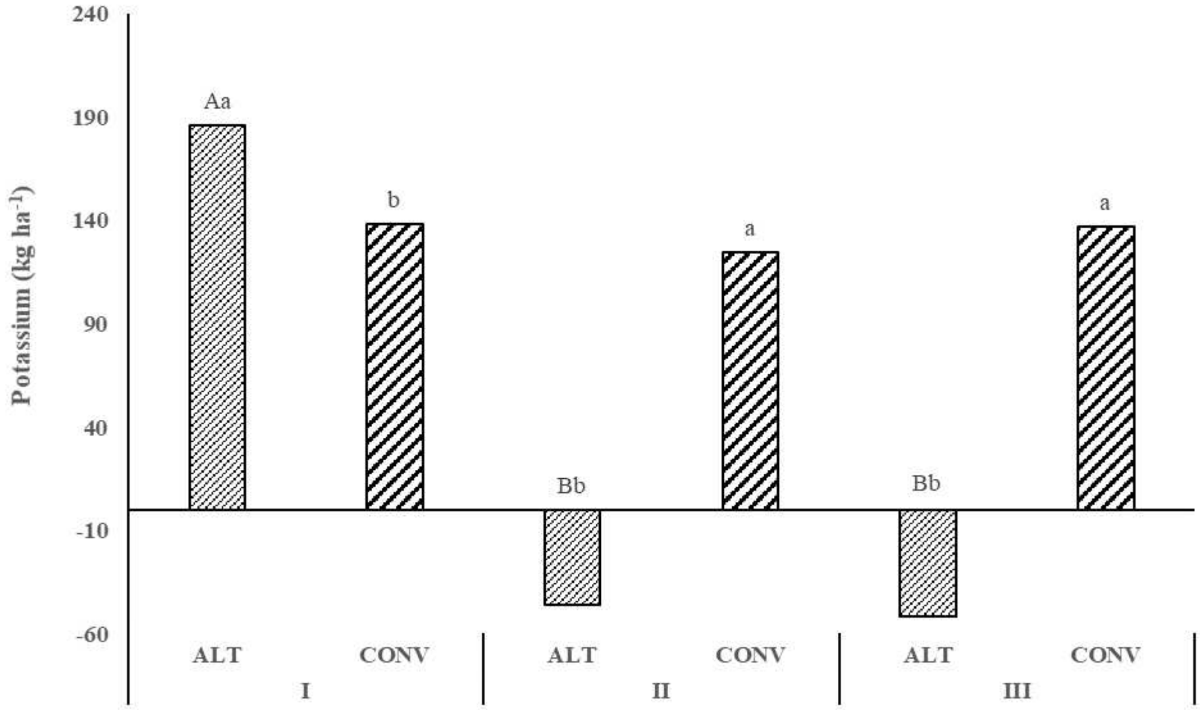

Figure 5 Potassium amount affected by growing season × management system interaction. Different lowercase letters indicate significant differences within the same growing season and between management systems ($P < 0.05$), different uppercase letters indicate significant differences among growing season within the same management system ($P < 0.05$) according to the Tukey's test (Number of replicates = 3).

The amount of N supplied in excess with respect to vegetable crop requirements is prone to reach adjacent ecosystems and cause water pollution (Cameira and Mota, 2017). Based on the N surplus indicator, the CONV cropping system had a remarkable excess of N compared with the ALT one. However, Sulas *et al.*, (2012), in similar condition found that N losses due to leaching were negligible in a nearby area, particularly in autumn. In the ALT management system, the high production was maintained at the cost of the soil organic N pool. The positive N balance was primarily due to the effect of the amount and quality (i.e., a low C/N ratio) of fresh crop residues returned to the soil, similarly to what was found by Constantin *et al.*, (2010). After three growing seasons in the ALT management system, we found that the retention of residues maintained a high and relatively stable agronomic productivity and use efficiently N inputs, thereby increasing sustainability. The pattern of the P and K budgets was similar, being the balance significantly different between CONV and ALT management systems. In ALT only a significant P and K deficit with a pattern opposite to N were calculated, whereas the CONV management apparently accumulated both P and K. For P, our results might be explained by the fact that cover crops do not necessarily increase of available P content in the soil, as observed by Ohm *et al.*, (2017)in their trial on organic systems. Nevertheless, it will be necessary to avoid soil P depletion with the application of suitable organic fertilizers to maintain P contents above the threshold value for a sufficient P supply to plants. Based on the soil K system budgets, the CONV system had unnecessarily high levels of K fertilization, which was also observed by Korsaeth, (2012) for arable conventional systems in a 10-year field experiment. Based on comparisons of nutrient budgets, the balances could vary widely within a management system. However, as general conclusion, alternative system promoted smaller nutrient surpluses than those of the conventional system, which should be an advantage, provided that nutrient reserves are not lost with leaching. The benefits of crop residue retention on agronomic productivity and sustainability are particularly important in soils such as those in Mediterranean areas, which are prone to erosion, drought, high soil temperatures, crusting or surface sealing, and hard-setting on drying (Lal, 2009).

3.3 Physiology activity

Physiology activity is the key parameter that can affect the post-harvest quality suitability of the artichoke heads destined directly to fresh market or storage and processing activity (Cefola *et al.*, 2012). Figure 6 shows the physiology activity of artichoke heads of Spinoso sardo varietal type collected in both CONV and ALT management systems during the 2020-21 growing season.

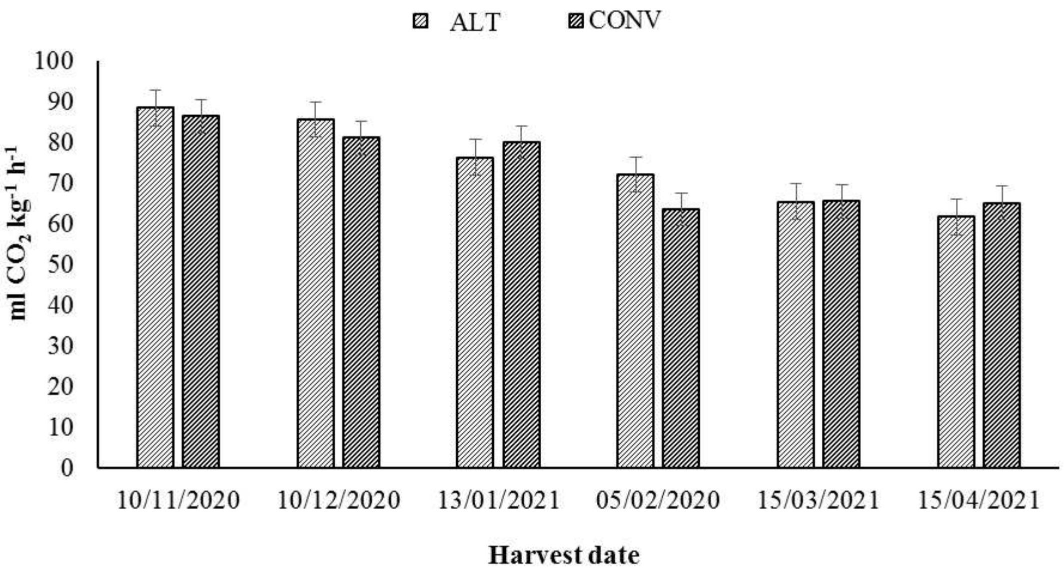

Figure 6: Respiratory activity as carbon dioxide release at 20 °C of globe artichoke obtained with conventional (CONV) or alternative (ALT) management system at different harvest period. Vertical bars represent standard deviation (n=6).

Globe artichoke heads showed a very high respiration rate in the initial period of harvest (winter period) with a steady decrease during the early spring period. The fluxes were equal to 90 ml CO_2 kg^{-1} h^{-1} in the artichoke heads collected in November-December and gradually reached 65 ml CO_2 kg^{-1} h^{-1} in the artichoke heads collected in April. The results showed that no significant differences were found between the respiratory activity of artichoke heads collected in ALT and CONV management systems.

Our respiration results showed that globe artichoke is, among the main fruit and vegetables, the one with a high respiratory metabolism and potentially subject to browning and senescence processes. A similar behavior was reported by (Kader, 2013) and can be explained by the rainfall and temperature trend observed in the experimental period in the Uri location. The climatic condition, particularly water availability and temperature, influences the quality and nutritional value of vegetables (Weston and Barth, 1997). The high precipitation in autumn and winter increases water potential gradients in tissues of plants and influenced positively the respiration activity of artichoke heads (Servani *et al.*, 2014). This effect, although not statistically different between managements, in the autumn and winter period was more evident in the ALT system, where the introduction of the cover crop could have improved soil aggregation, water infiltration, water retention, and plant available water, influencing indirectly physiology parameter of respiration (Blanco-Canqui and Jasa, 2019).

Knowledge of this parameter and its variation as a function of harvest time is of fundamental importance for the post-harvest management of the artichoke as a fresh marketed product and for the identification of the most suitable technologies for preserving the organoleptic and nutritional quality characteristics, particularly, in modern consumers extremely careful to the nutraceutical and health-promotional food (Stefanelli *et al.*, 2010).

As reported by (Moretti *et al.*, 2010), the respiration rates of vegetables are influenced by the temperature with strong implications for crop quality in terms of ratio between photosynthesis and respiration in the process of maturity of vegetables. The effects of carbon dioxide release of globe artichoke heads cv. Spinoso sardo at different post-harvest temperatures was reported in figure 7.

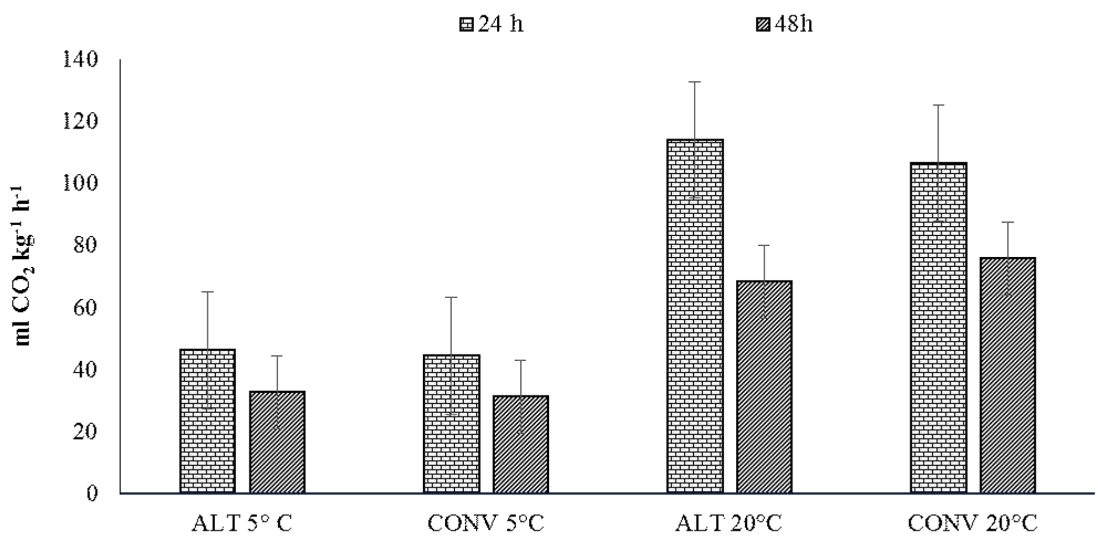

Figure 7: Respiratory activity as carbon dioxide release at 5 °C and 20 °C of globe artichoke (cv. Spinoso sardo) after 24 and 48 h from the harvest. Vertical bars represent standard deviation (n=6).

The CO_2 rates of artichoke heads showed different values according to the temperature monitored at 24 and 48 hours from the harvest. Specifically, respiration activity was significantly higher at 20 °C compared to 5 °C for both management systems achieving mean values of 100 ml CO_2 kg^{-1} h^{-1} in heads collected in ALT management and 105 ml CO_2 kg^{-1} h^{-1} in heads collected in CONV management at 24 hours of the harvest. The lowest values were monitored at 48 hours from the harvest and they were equal to 70 ml CO_2 kg^{-1} h^{-1} and 75 ml CO_2 kg^{-1} h^{-1} in ALT and CONV management respectively always at 20 °C. Lower carbon dioxide activity of samples has described when artichoke heads were stored at 5 °C for both compared management. After 24 hours from the harvest at 5 °C, the values of CO_2 rates were about 45 ml CO_2 kg^{-1} h^{-1} in artichoke heads collected in both management systems with no significant differences between them. A gradual decrease in respiration activity after 48 hours from harvesting with mean value of 33 ml CO_2 kg^{-1} h^{-1} was also observed. Our results agree with Gil-Izquierdo *et al.*, (2002) that reported similar values at refrigeration temperature of 5 °C for cv Blanca de Tudela artichoke and with (Restuccia *et al.*, 2014) for cv. Violet de Provence, Romanesco, and clone C3, respectively. As expected, the respiration of globe artichoke heads stored at 5 °C was much slower than that of the products maintained at room temperature. This trend reflects the ratio between photosynthesis and respiration in the process of maturity of vegetables post-harvest (Peiris *et al.*, 1997). Higher temperatures accelerate the respiration rate and reduce net carbohydrate reserves leading to post-harvest life with senescence of head artichoke (Del Nobile *et al.*, 2007). Our results underline that a strict temperature control is extremely important for reducing metabolic activity for maintaining quality of heads artichoke during post-harvest in particularly in the storage and shipping phases.

3.4. Chemical parameters

Carbohydrate content

Among the biochemical constituents of globe artichoke, sugar, and oligosaccharides, in particular, constituted the main compounds in dry matter and they play an important role in stimulating the artichoke growth following the summer seasonal dormancy and nutritional benefits as they enter to the human diet (Lattanzio *et al.,* 2002; Raccuia and Melilli, 2010). Most of the calories in globe artichokes heads come from carbohydrates fraction that includes fiber, starch, and simple sugars. Little information is available in the literature on the sugar content of artichoke heads but with this study, we may provide detailed information about the total sugar content of artichoke heads and the individual sugar fractions (sucrose, glucose, and fructose) at different harvest times and for different management systems. In figure 8 are reported the seasonal profile of the total sugar concentration of artichoke heads, in the November-April harvest period. In the head, considered as a whole, total sugar content, increased over along the harvest period from values of about 1.9 g 100 g^{-1} in November to about 2.3 g 100 g^{-1} on the fresh product of April period resulting not statistically influenced by management adopted and harvest date.

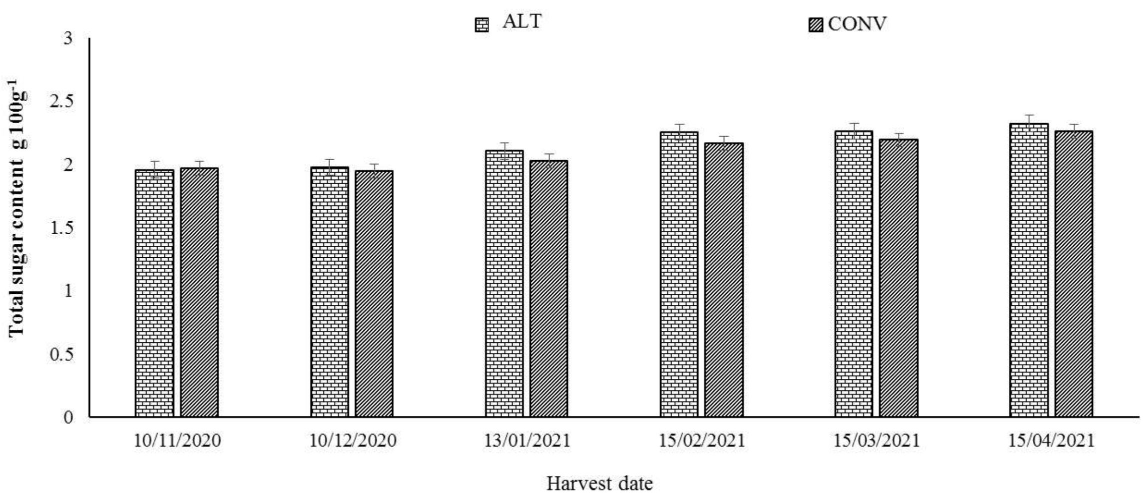

Figure 8: Total sugar content of globe artichoke obtained with CONV or ALT management system at different harvest period. Vertical bars represent standard deviation (n=3).

Concerning the single components of sugar, our results showed as the major class is represented by glucose followed by fructose and sucrose (figg. 9-11).

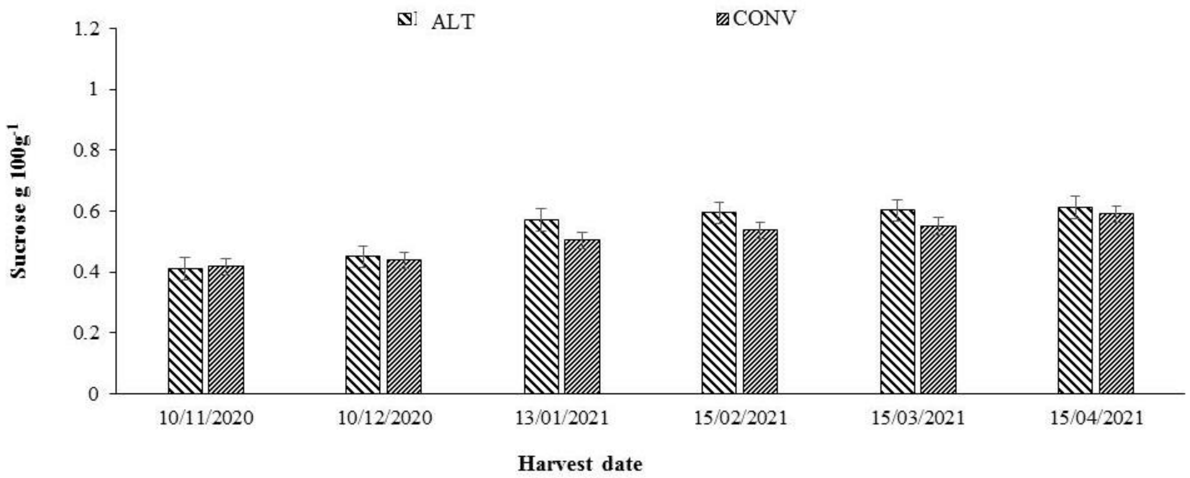

Figure 9: Sucrose content of globe artichoke obtained with conventional (CONV) or alternative (ALT) management system at different harvest period. Vertical bars represent standard deviation (n=3).

The average sucrose content in the heads increased progressively as the harvest date progressed, ranging from values of 0.4 g 100 g^{-1} in fresh globe artichokes harvested in November to 0.6 g 100 g^{-1} in artichokes harvested in April with no statistically significant differences between CONV and ALT systems (fig. 9).

In our study, the glucose content measured in fresh products increased from 0.9 g 100 g^{-1} in artichokes harvested in November to 1.1 g 100 g^{-1} in those harvested in April (fig. 10). The fructose content remained constant throughout the harvest period ranging mean values between 0.6 g 100 g^{-1} on the fresh product (fig. 11). Our results contrast with those of (Raccuia and Melilli, 2004), that analyzing the single sugar components have found a glucose content lower in *Cynara* genus equal to 0.27 g 100 g^{-1} of glucose, and 0.20 g 100 g^{-1} of fructose content. A similar value instead was observed for sucrose content (0.59 g 100 g^{-1}).

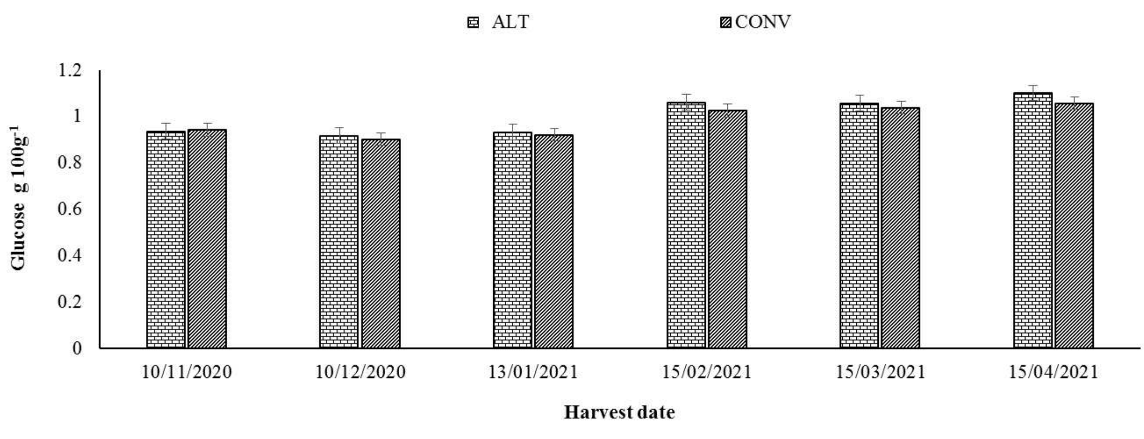

Figure 10: Glucose content of globe artichoke obtained with CONV or ALT management systems at different harvest period. Vertical bars represent standard deviation (n=3).

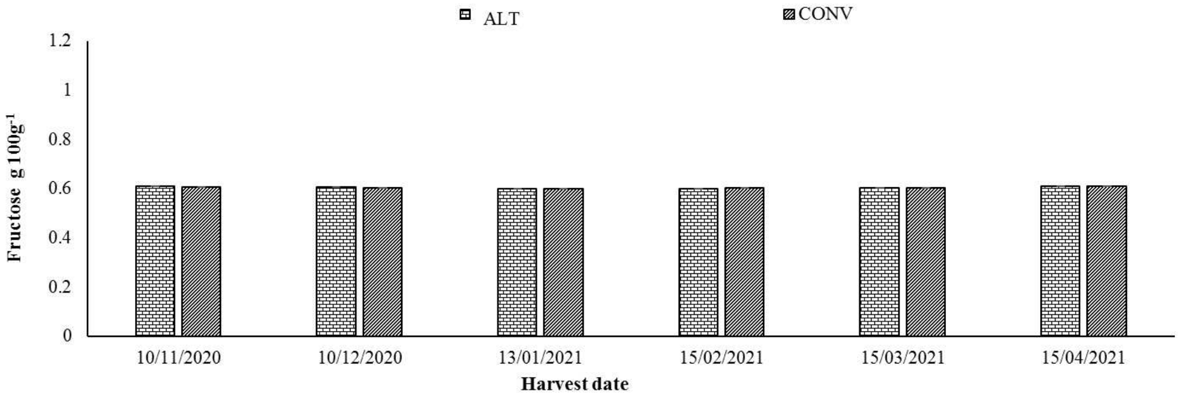

Figure 11: Fructose content of globe artichoke obtained with conventional or alternative management systems at different harvest period. Vertical bars represent standard deviation (n=3).

The higher amount of glucose content observed in the April period could be linked with the high temperatures recorded at the Uri location during the March and April months compared to the long-term weather series. This variation of temperature conditions may have determined an increased osmotic potential regulation and cryoprotection in plant cells aimed to overcome stress conditions during artichoke head development with an increase of the carbohydrate translocation toward artichoke heads (Mandim *et al.*, 2020). The high amount of sugars, along the all-growing cycle, confirms the good nutritional value of the globe artichoke heads varietal type Spinoso sardo. The study site characteristics associated with a good environmental climate and alternative management systems offer the opportunity at the farm to produce globe artichoke heads characterized by high nutritional quality without compromising environmental sustainability.

Fiber content

The fiber content of artichoke varietal type Spinoso sardo expressed as fiber to neutral detergent (NDF), fiber to acid detergent (ADF), and lignin to acid detergent (ADL), determined over the harvest period is shown in figure 12.

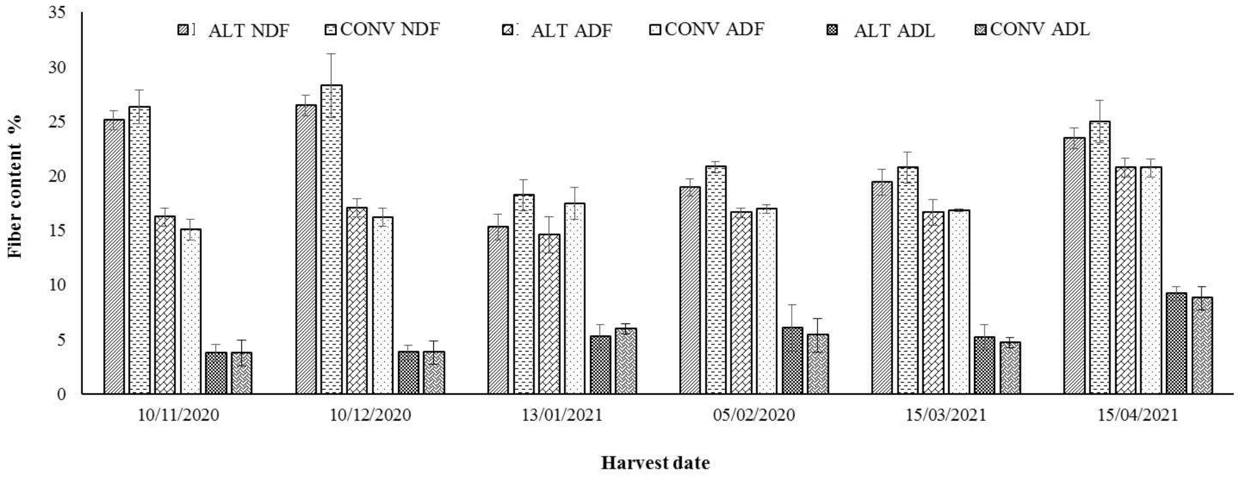

Figure 12: Fiber content of globe artichoke obtained with CONV or ALT management systems at different harvest period. Vertical bars represent standard deviation (n=3).

Fiber concentration is usually influenced by many factors such as the stage of plant development and environmental conditions (i.e., drought, temperature, photoperiod etc.) or availability of nutrients (Peterson *et al.*, 1992; Fulkerson *et al.*, 2007). The NDF content detected was highest in the artichoke heads harvested in the November-December period, reaching values of about 26%, while the lowest values were found in the late winter period, with values varying between 15 and 20%, remaining stable until the end of the crop cycle in April. Similarly, ADF fiber content varied, but without statistical differences between the two managements adopted, in the November-April harvest period. The values ranged from approximately 13 and 16% of the late autumn to 18 and 20% of the late spring. An opposite trend was observed for ADL fiber content. Specifically, ADL content showed lower values in the early period of harvest reaching values included of 3 and 5% with an increase of +125% at the end of the harvest period. The trend of three fiber content revealed in the study agrees with the results reported by Sulas *et al.*, (2016) and Ferrero *et al.*, (2020) on *Cynara cardunculs* (L.) species cultivated in Mediterranean area. The authors reported that the fiber composition of genus is mainly influenced by the crop vegetative stage with a reduction of NDF and ADF content at the stage of maturity of the crop and at the same time a positive correlation of acid detergent fiber content. In our experiment, no marked difference emerged from the two managements adopted on ADF, NDF, and ADL contents. Specifically, NDF content (cellulose, hemicellulose, and lignin) was lower in ALT management in all growing seasons analyzed suggesting a positive interaction of management and quality of artichoke heads. This phenomenon could be attributed to a possible synergic effect between rhizosphere bacteria of cover crop and main crop (Gupta *et al.*, 2015) that promote synthesis of plant growth compounds that improve ability for nutrient uptake (nitrogen, phosphorus, potassium, and essential minerals) from the soil.

Our findings are in contrast with (Allahdadi *et al.*, 2020), that observed positive effects in fiber content in cultivation of globe artichoke conducted according to conventional management. The results obtained in our study highlight the potentiality for the application of an agroecological management system, in term of environmental and economically sustainability with advantage in the reduction of mineral fertilizer supply, underground water pollution but at the same time maintaining a high nutritional quality of globe artichoke heads.

Total phenolic content and antioxidant activity

Globe artichokes are characterized by having a high content of phenolic compounds that impact their chemical composition, taste, color, and astringent mouthfeel as well as antioxidant and nutraceutical properties (Lombardo *et al.*, 2015). The total phenolic content according to study conducted by (Lombardo *et al.*, 2018) is influenced by various factors such as agronomic practices adopted, soil and climate conditions, and genetic aspects.

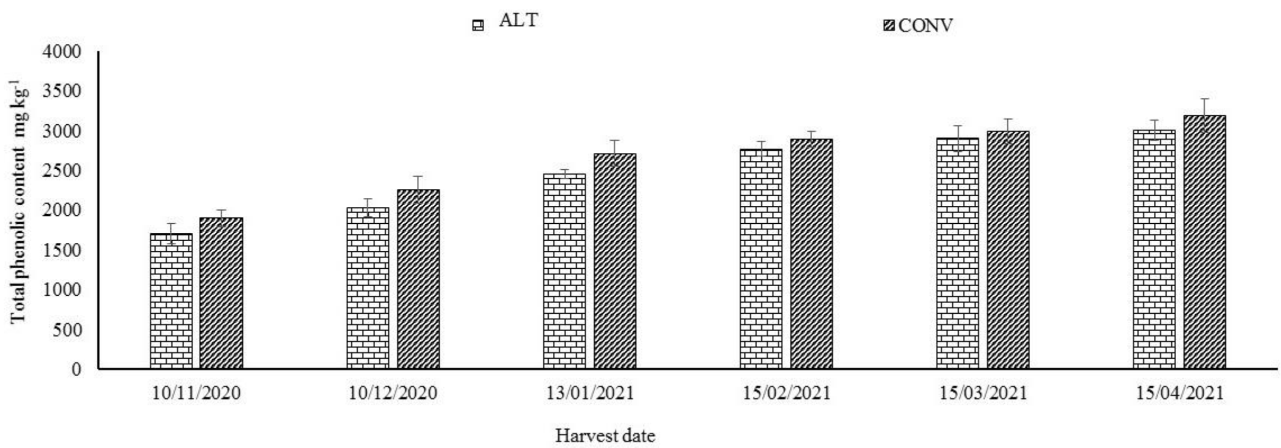

Figure 13: Total phenolics content as gallic acid equivalent of globe artichoke obtained with conventional or alternative management systems at different harvest period. Vertical bars represent standard deviation (n=3).

In figure 13 was reported the total phenolic content (TPC) in artichoke heads of the cv. Spinoso sardo expressed as milligram gallic acid equivalent (mGAE) per kg of fresh product collected in CONV and ALT managements. It was found that the level of TPC in the artichoke head was approximately 1800 mGAE kg^{-1} in the initial period of harvest (autumn-winter) then increase for all period analyzed, in particularly reaching the maximum value of 3000 mGAE kg^{-1} in early spring, with no significant differences between head artichokes collected in ALT and CONV managements. Our results confirmed the hypothesis that TPC in head artichoke depends on the plant age (de Falco *et al.*, 2015) but especially underline that the heads harvest in the spring period (3rd order and following) has a major polyphenol content compared to artichoke heads collected in early winter (1st and 2nd order). In this way, from a nutritional point of view, heads picked at the end of the growing season might be most suitable for fresh consumption due to their high biological and nutritional value.

To support this hypothesis in the spring period as for TPC, antioxidant activity of the extracts showed the highest value (0.8 mmol kg^{-1} TEAC) positively correlated with the evolution of the total phenol content (Cefola *et al.*, 2012) but with no statistically significant differences observed for both managements (fig. 14). During the winter period instead the antioxidant activity decreases by -37.5% on average, reaching a mean value of 0.5 mmol kg^{-1} TEAC.

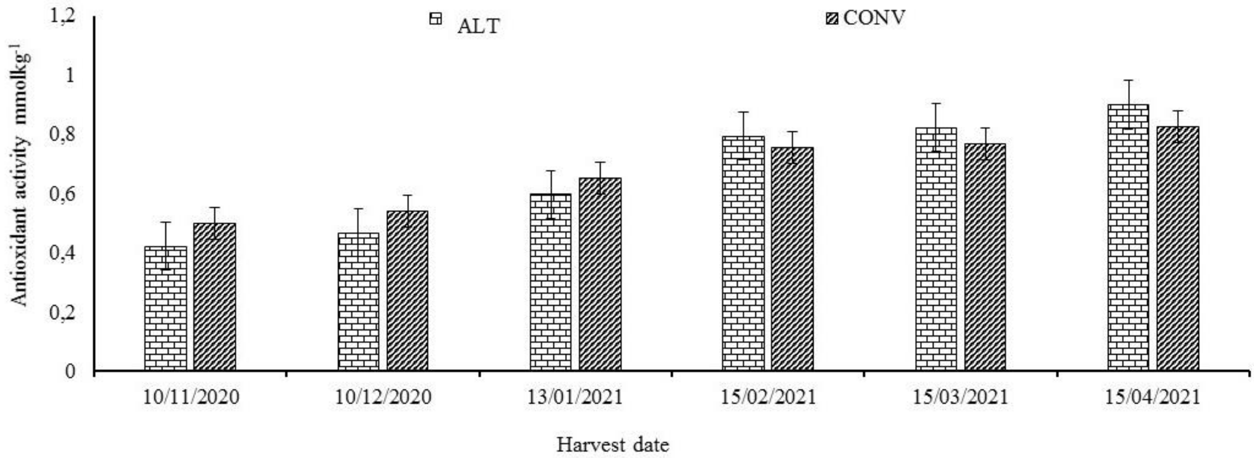

Figure 14: Changes in antioxidant activity as trolox equivalent (TEAC) of globe artichoke obtained with CONV or ALT management system at different harvest period. Vertical bars represent standard deviation (n=3).

The high TPC values observed at the last artichoke harvest period are consistent with those observed by Pandino, Lombardo, and Mauromicale, (2013) who reported an increase of TPC on the head globe artichoke cv 'Violetto di Sicilia' during the harvest time between November to April. This trend could be explained according to two hypotheses. The first hypothesis suggests that increase of TPC is related to environmental conditions that occurred in the harvest period. Specifically, temperatures decrease in the winter period can induce a progressive increase in the production of secondary metabolites and in particular polyphenolic substances as a response of the plant to low temperature (Di Venere *et al.*, 2005; Ricci *et al.*, 2013). Furthermore, the higher production of the secondary metabolites in spring season might be the consequence of the increase in cellular antioxidant enzyme activity due to high temperature and water stress that occurred in early April during the intensive head development stage (Tan *et al.*, 2006). Similar results were found by Lombardo *et al.*, (2010) that observed a positive correlation of environmental stress on the TPC. The second hypothesis suggests that the adoption of biological control with mycoparasitism inoculated in the soil at the establishment of crop in July (e.g. *Trichoderma* ssp.) might stimulate the production of biochemical compounds of phenolic nature associated with the crop defense (Surekha *et al.*, 2014).

According to Spanu *et al.*, (2018) our findings confirmed that the adoption of an agroecological approach in globe artichoke cropping systems maintains in the short term the quality of heads with the advantage to promote the overall sustainability of agroecosystem.

Phenolics compounds detected

A representative HPLC chromatogram of the phenolic compounds extracted from fresh artichoke heads determined at a wavelength of 330 nm is shown in figure 15. Six major peaks were separated with elution times of 15, 28, 53, 55, 56, and 62 min. In the chromatogram other eluted peaks were detected, but it was not possible to identify and quantify them because their concentrations were below the detection limit of the instrument or because they were not completely separated.

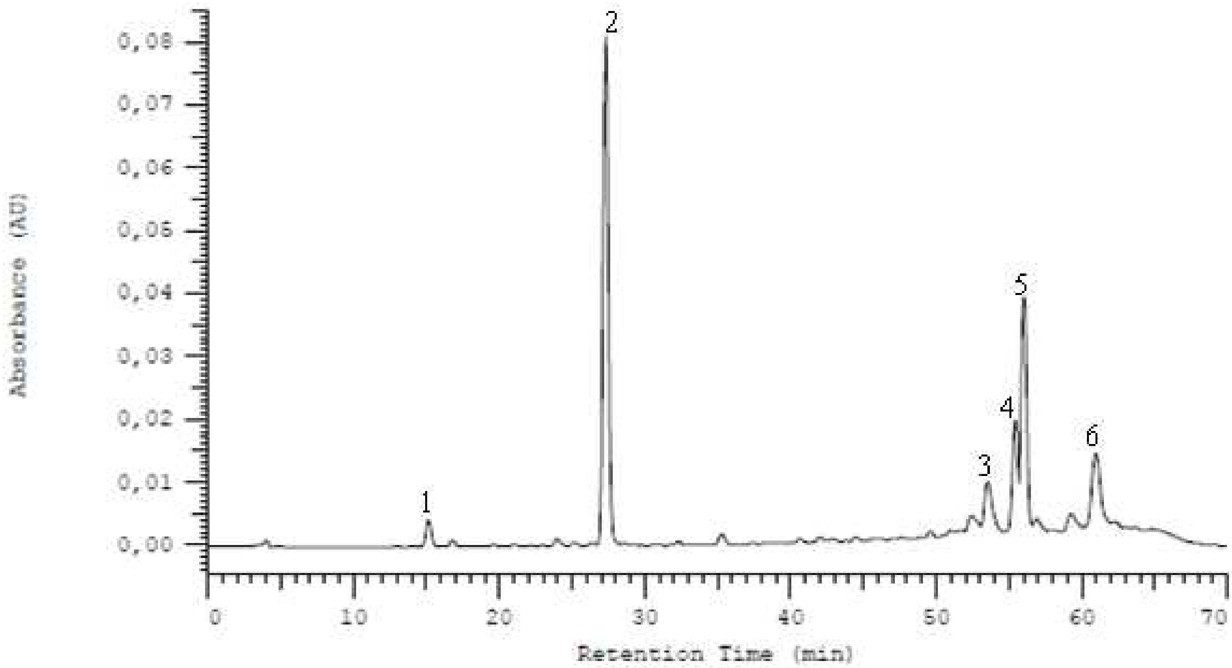

Figure 15: HPLC chromatogram at 330 nm of globe artichoke extract. Identified compounds: (1) neo-chlorogenic acid; (2) chlorogenic acid; (3) 1-O-dicaffeoylquinic acid; (4) 3,5-O-dicaffeoylquinic acid; (5) 1,5-O-dicaffeoylquinic acid; (6) apigenin 7-O-rutinoside.

In our study, the main phenolic compounds found in the artichoke heads are caffeoylquinic acids and a small percentage of flavonoids (<10%). This qualitative analysis was already confirmed in previous works on globe artichoke, conducted by (Lombardo *et al.*, 2012; Pandino *et al.*, 2013). In the peak levels of the first class of polyphenols predominate chlorogenic acid (2) followed by 1,5-O-caffeoylquinic acid (5). Other caffeoylquinic acids identified were neo-chlorogenic acid (1), 1-O-Dicaffeoylquinic acid (1), and 3,5-O-Dicaffeoylquinic acid (4), while among the flavonoids, apigenin 7-Orutinoside was identified (6). The amounts of each component are extremely variable and might be influenced by numerous factors such as the variety, environmental conditions, harvesting period, and agronomical management (Mošovská *et al.*, 2015). The effects of management, harvest date, and their interaction on the total polyphenol composition detected in Spinoso sardo varietal type are presented in table 3. Statistical differences were observed in all phenolic compounds analyzed except for the 1-O-DQA among harvest dates, showing a positive correlation with the harvest period. The highest phenolic concentration in artichoke heads was found for chlorogenic acid (2) with an average concentration of about 0.69 g kg^{-1} on the fresh matter in winter and of 1.21 g kg^{-1} on the fresh matter in the spring period, followed by 1,5-O-caffeoylquinic acid (5) with average concentrations of about 0.36 g kg^{-1} (winter) and 0.68 g kg^{-1} in spring period (tab. 3). In our study, in contrast to what was reported by other authors (Faller and Fialho, 2009; Spanu *et al.*, 2018) (Alamanni and Cossu, 2003, management system did not significantly influenced the qualitative and quantitative composition of the phenolic component in artichoke heads. The differences observed among harvest dates appear to be linked to genetic factors (Moglia *et al.*, 2008; Negro *et al.*, 2012), climatic conditions (Lombardo *et al.*, 2009), and different extraction and analysis methods. Specifically, heat stress occurred in the spring period (+ 1 °C) compared to the long-term weather series might have influenced physiological and metabolic processes in the artichoke plant (Zeipina *et al.*, 2016). In particular, these stress-induced in artichoke heads maturity stage can inhibit the crop photosynthetic activity promoting the biosynthesis of antioxidant compounds especially caffeoylquinic acids as a heat and drought stress avoidance mechanism for the plant (Nouraei *et al.*, 2016). Our findings confirm that the good nutritional and nutraceutical characteristic in the edible part of the globe artichoke plant obtained with agroecological practices, combined with the enhanced interest for functional foods by consumers, may encourage the globe artichoke consumption on a wider scale.

Table 3. Changes in phenolic compounds concentration g kg^{-1} detected in globe artichoke obtained with conventional or alternative management system at different harvest period.

	NA		CA		1-O-DQA		3,5-O-DQA		1,5-O-DQA		A7-O-R	
Harvest date	**CONV**	**ALT**	**CONV**	**ALT**	**CONV**	**ALT**	**CONV**	**ALT**	**CONV**	**ALT**	**CONV**	**ALT**
10/11/2020	0.064	0.060	0.652	0.749	0.014 b	0.014 b	0.198 bc	0.147	0.401 c	0.312 d	0.152 c	0.149 c
10/12/2020	0.067 c	0.057 c	0.652 c	0.749 c	0.015 b	0.014 b	0.212 bc	0.142 c	0.429 c	0.298 d	0.169 c	0.121 c
13/01/2021	0.067 c	0.070 c	0.669 c	0.721 c	0.011 c	0.014 b	0.256 ab	0.212 bc	0.504 bc	0.453 c	0.171 b	0.181 b
15/02/2021	0.069 ab	0.068 c	0.971 ab	1.101 b	0.015 b	0.021 a	0.337 a	0.264 ab	0.677 a	0.616 ab	0.196 ab	0.192 ab
15/03/2021	0.110 a	0.096 ab	1.176 a	1.192 a	0.015 b	0.022 a	0.351 a	0.339 ab	0.696 a	0.653 ab	0.210 a	0.222 a
15/04/2021	0.115 a	0.085 a	1.190 a	1.222 a	0.014 b	0.020 a	0.362 a	0.357 ab	0.726 a	0.672 ab	0.234 a	0.243 a

*Values in column for each harvest date not followed by the same letter are significantly different at $P \leq 0.05$ according to Duncan's multiple range test (n=3). NA (Neochlorogenic acid), CA (Chlorogenic acid), 1-O-DQA (1-O-Dicaffeoylquinic acid), 3,5-O-DQA (3,5-O-Dicaffeoylquinic acid), 1,5-O-DQA (1,5-O-Dicaffeoylquinic acid), A7-O-R (Apigenin 7-O-rutinoside).

4. CONCLUSIONS

In our experiment we studied globe artichoke Spinoso sardo varietal type grown according to an alternative management based on different agroecological practices such as cover crop use, rational crop residues management and no chemical fertilizers application. The results highlighted that this alternative management, could be successfully used both for reducing the use of mineral fertilizers and for obtaining head yield of Spinoso sardo not statistically different from those obtained in the conventional management. Concerning the macronutrients balance in absence of mineral fertilization, the adoption of a legume cover crop promoted a valuable nutrient recycling without any nutrient deficit. The results obtained in our comparative study concerning the nutritional and nutraceutical aspects of artichoke heads of the Spinoso sardo varietal type grown according to sustainable or conventional agronomic practices showed no significant differences in the physiological activity, fiber content, sugars, total phenols, antioxidant activity and the quantitative and qualitative components of the main phenolic compounds identified. By picking up the heads at monthly interval throughout the growing season (November-April), we observed that as the harvesting season progressed, an increase in the content of the phenolic component, in the antioxidant activity and in the sugar content was recorded, while the fiber content remained almost unchanged regardless of the agronomic practice adopted.

In conclusion, globe artichoke grown according to an agroecological approach is a viable option and fulfils a dual function: it contributes to environmental protection and provides consumers with a product characterized by greater food safety with nutritional and nutraceutical properties similar to the product obtained using conventional cultivation methods.

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