Quality traits of globe artichoke ecotypes from Sicilian small holdings

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Abstract

In Sicily (South Italy), together with the widely cultivated genotypes, several globe artichoke ecotypes are traditionally cultivated for either self-consumption or destination of capitula to local markets. With a view to safeguard this agrobiodiversity from the risk of extinction, due to the introduction of the most profitable commercial and exotic genotypes, our aim was to elucidate some quality characteristics of 18 Sicilian ecotypes in order to valorize them for specific end-uses. Our results highlighted as some of the considered morphological (i.e. capitulum fresh weight and receptacle incidence) and nutritional (i.e. total polyphenols content) characteristics were able to distinguish the globe artichoke ecotypes. Among the evaluated nutritional traits, the total polyphenol content (TPC) appeared to be strongly affected by genotype and may be used as a target trait for diversifying the end-uses of these ecotypes. In this respect, 'Santa Domenica Vittoria' and 'Monterosso Almo', which presented a higher TPC in the receptacle (edible part), may be probably best suited for the fresh consumption. By contrast, some ecotypes (e.g. 'Belpasso' and 'Quartarella') seemed more suitable for food processing due to their low TPC in the receptacle and less tendency to total color changes after cutting.

Keywords: globe artichoke, ecotypes, capitulum, morphology, total polyphenols, ascorbic acid, color

INTRODUCTION

Globe artichoke [*Cynara cardunculus* L. var. *scolymus* (L.) Fiori] is an important vegetable crop mainly cultivated in the Mediterranean area, where its wild progenitor and other species of the genus *Cynara* also grow (Portis et al., 2012). Nowadays Italy is the main global globe artichoke producer, with a cultivated area of ~38 kha and a mean annual production of capitula equal to 372 kt (FAO, mean data 2020-2021).

The national production is mainly based on a few highly heterozygous and vegetatively propagated varietal types (Lombardo et al., 2018). However, Italy holds the greatest globe artichoke biodiversity, including several vegetatively propagated varietal groups with high level of heterozygosis (Portis et al., 2012), ecotypes and landraces (Mauro et al., 2009). These have been differentiated based on of capitulum morphology (shape, bract color, presence/absence of spines) and harvest time (Lombardo et al., 2018), as well as in the content of inulin, various minerals and polyphenols (Lattanzio et al., 2009; Lombardo et al., 2015, 2017a; Pandino et al., 2012a, 2017). The number of genetically distinguishable clones under cultivation may be difficultly counted, and only 11-12 are considered commercially relevant (Lombardo et al., 2018). In Sicily, one of the possible centers of globe artichoke domestication, local farmers usually cultivate populations of landraces in small holdings; these genotypes typically yield less than commercial varieties, but are well suited for specific end-uses, are more tolerant to abiotic stress and more adaptable to low crop management inputs (Mauro et al., 2009).

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The two autochthonous and most cultivated Sicilian genotypes 'Spinoso di Palermo' and 'Violetto di Sicilia' are thought to have emerged from such small holdings (Mauro et al., 2009). Although they are largely cultivated thanks to their high adaptability, early flowering habit and acceptability to consumers, their heterozygosis provoked unreliable yield potential and variability in capitulum morphological and qualitative traits (Mauro et al., 2009; Pandino et al., 2012a). Hence, the local farmers are replacing them with exotic genotypes (e.g. 'Tema 2000', 'Violet of Provence') and seed-propagated F_1 hybrids (Foti et al., 2005; Lombardo et al., 2018). In this respect, the goal of this study was to characterize, from both the morphological and qualitative standpoints, 18 globe artichoke ecotypes collected in small holdings and maintained at the Catania University experimental station until now. Among the nutritional traits, the content of total polyphenols and ascorbic acid, health-promoting compounds, were evaluated since appear to be strongly affected by the gene pool (Pandino et al., 2012a). In addition, capitulum biometrical traits, receptacle color changes and resistance after cutting were assessed. This may allow to select ecotypes for specific end-uses (fresh market, industrial processing and bioactive compounds extraction) (Barbagallo et al., 2007; Muratore et al., 2015; Scavo et al., 2019) and, hence, preserve them from the risk of genetic erosion.

MATERIALS AND METHODS

Plant material, experimental site and management practices

During the early summers of 2004 and 2005, 18 globe artichoke ecotypes were collected from Sicilian small holdings located at sites varying in altitude from 12 to 1,000 m a.s.l. (Mauro et al., 2009). For most of these sites, there was no intensive cultivation of globe artichoke (Mauro et al., 2009). Semi-dormant offshoots ('ovoli') were rapidly transplanted into the experimental station of Catania University located on the Catania Plain (South Italy) (37°25'N, 15°30'E, 10 m a.s.l.), in a typic and/or vertic xerochrepts soil (USDA, Soil Taxonomy). The Catania Plain is a typical area for globe artichoke cultivation in Italy and characterized by a typical semi-arid Mediterranean climate with mild winters and hot dry summers.

A living collection was being maintained in the experimental field of the University of Catania until now. Globe artichoke ecotypes were systematically replanted every two-three years. The plant material ('ovoli') was planted 0.80 m apart within each row with an interrow spacing of 1.25 m, to give an overall density of 1 plant m^{-2}. The material was arranged in a randomized block design with 4 replications, with about 10 plants per each ecotype. Every year prior fertilization was carried out with 70-150 and 150 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Another application (as ammonium nitrate) was done at a rate of 130 kg ha^{-1}, when the lateral offshoots had been removed manually (early February). Subsequent crop management practices (irrigation, weed and pest management) were performed as per local practice.

The data in the present work are referred to the 2016-17 growing season.

Morphological characterization

At least 20 capitula, with floral stem, per each ecotype and replicate, at the usual marketing stage, regardless of their size, were harvested disease-free in February-March. At this stage, the length of the central global flower buds was ≤2 mm (Pandino et al., 2022a). The following traits were assessed: mean fresh weight of the capitulum, the ratio between the longitudinal and transverse diameter of the capitulum (L/D ratio), receptacle incidence on the whole capitulum fresh weight, and floral stem length.

Chemical characterization

Ten capitula per ecotype and replicate were cleaned and separated into bracts, receptacles and floral stems. Then, 3 receptacles per each ecotype and replicate were used for cutting resistance evaluation, the other 3 receptacles for the total color changes assessment and the remaining for the chemical characterization. In the latter case, each capitulum part (i.e. receptacle, bracts, floral stem) was firstly sliced using a domestic food processor at 0°C (Kenwood multipro, Milan, Italy). Finally, an amount of each capitulum fraction was oven-

dried at 65°C (Binder, Milan, Italy), until a constant weight was reached, to determine the dry matter (DM) content; another part of the homogenized fresh sample per each capitulum part was freeze-dried for the ascorbic acid (only receptacle) and total polyphenols determinations.

Total polyphenols content (TPC) was quantified according to Licciardello et al. (2017) and expressed as g chlorogenic acid equivalent kg^{-1} DM.

Ascorbic acid (AsAc) content was determined in the receptacle by adapting the 2,6-dichlorophenolindophenol dye method proposed by Lombardo et al. (2013). The AsAc content was expressed as mg kg^{-1} DM.

Total color difference evaluation

The color evaluation was done in CIE L-a-b system, using a Minolta CR 300 colorimeter with illuminant D65, calibrated against a white-standard before each session. Three receptacles for ecotype and replicate were cut longitudinally and immediately (zero time), in each half, two readings were made in the largest diameter area. In order to assess the possible phenomenon of enzymatic browning, the same receptacles, after being cut, were left at room temperature for 20 s and color measurements were repeated. The differences in L, a and b values from zero-time readings were combined to obtain a total color difference (ΔE) (Pathare et al., 2013). A larger ΔE means a greater color change from the reference material.

Cutting resistance evaluation

Cutting resistance of fresh receptacles was evaluated using a digital penetrometer (TR Turoni mod. 53205, Forlì, Italy), equipped with a specific shear probe tip. For each replicate, two measurements were made in the core region of 3 receptacles cut in equal halves. The samples were placed perpendicular to the blade and the maximum force (cutting resistance), required for penetrating the samples to about 10 mm, was measured in Newton cm^{-2} (N cm^{-2}).

Statistical data analysis

Data were first tested for homoscedasticity using Bartlett's test, then subjected to ANOVA. Means were separated using Tukey's HSD test, with a minimum level of acceptance of $P<0.05$. Percentage data were Bliss-transformed before ANOVA. The coefficient of variation (CV%) per each morphological and qualitative parameter was calculated.

RESULTS AND DISCUSSION

The ecotypes varied widely for the morphological parameters under study (Figure 1). The capitulum averaged fresh weight was a highly discriminant trait (CV=21%), ranging from 105 to 205 g. 'Belpasso' and 'Quartarella' produced the heaviest capitula, while 'Femminello di Marsala', 'Cimiciusa di Mazzarino 2' and 'Caltagirone' were the smallest ones (Figure 1). The ecotypes also significantly differed concerning both the floral stem length (CV=25%) and receptacle incidence (CV=26%). The latter varied from 15.6 ('S. Giacomo 3') to 35.1% ('Cimiciusa di Mazzarino 2'). Together with 'Cimiciusa di Mazzarino 2', 'Spinoso di Sciara' and 'Domestica di Castelvetrano' displayed the highest receptacle incidence. This is interesting for both the fresh market and industrial processing end-uses, in order to have lower waste materials. The floral stem length was the highest in 'Spinoso di Sciara' and 'Giarratana', followed by 'S. Giacomo 3' and 'Monterosso Almo'. The lowest values were reported for 'Naro 3' and 'Naro 4' (Figure 1). On the contrary, our results showed that L/D ratio, an important index of capitulum shape, was a relatively constant trait among ecotypes (CV=9%), varying from 0.9 ('Quartarella') to 1.4 ('Giarratana') (Figure 1). However, there was a predominance of a long shape of the capitulum, since 9 of 18 ecotypes had a L/D superior to 1.2.

The DM content was more variable in the bracts and floral stem (CV=17 and 16%, respectively) than in the receptacle (CV=13%) (Figure 2). Among the ecotypes, 'Spinoso di Sciara' and 'Cimiciusa di Mazzarino 2' showed the highest DM levels in both the receptacle and floral stem. 'Cimiciusa di Mazzarino 2' also displayed the highest DM content in the bracts (18.9%), followed by 'Femminello di Marsala' (17.0%).

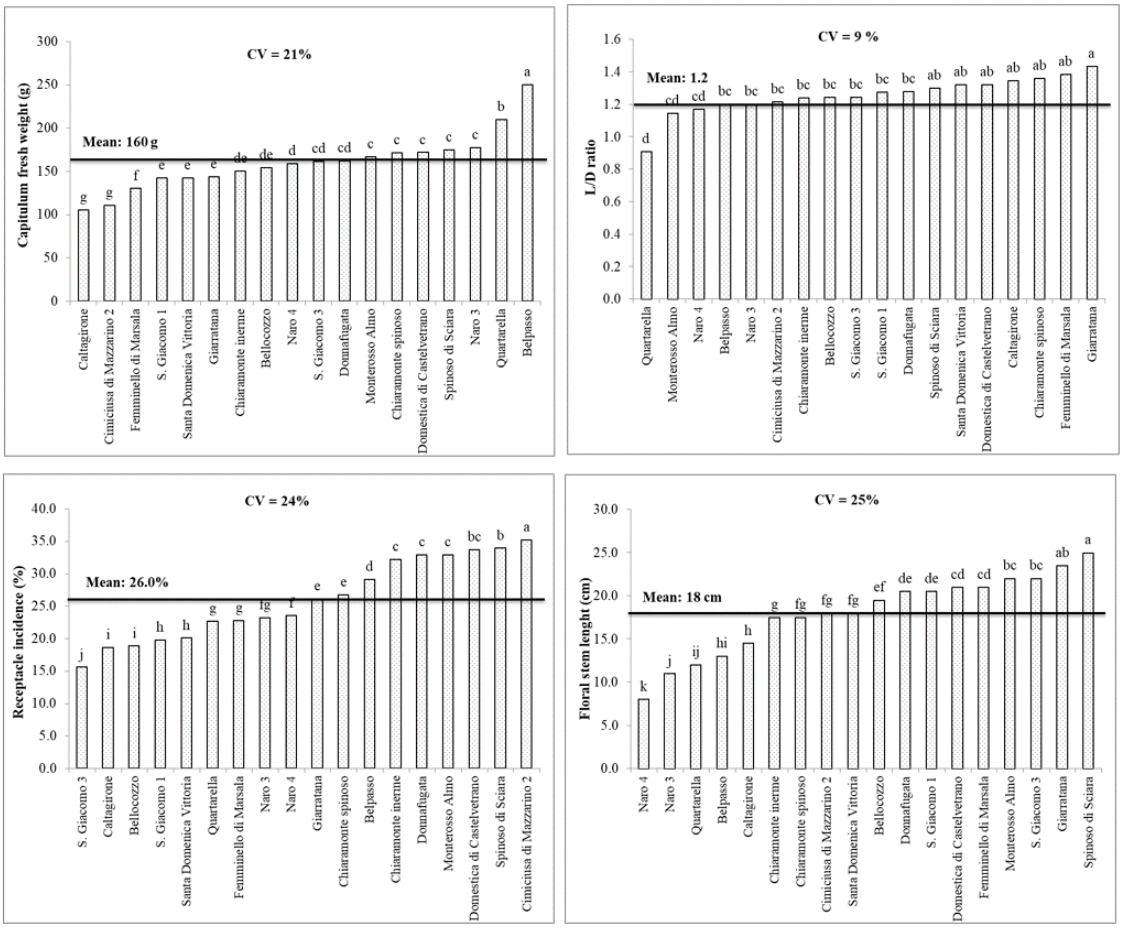

Figure 1. Morphological traits of the globe artichoke ecotypes under study. Different letters within each parameter indicate statistically differences among means (Tukey's HSD, $P \leq 0.05$). The horizontal black lines indicate the global mean per each trait.

Looking at the TPC (Figure 2), it varied widely in the floral stem (CV=29%) and receptacle (CV=30%) with respect to the bracts (CV=13%). Recently, Lombardo et al. (2018) reviewed as the genetic variability has a strong impact on TPC; however, many other pre- and post-harvest factors often interact, producing substantial variation on the globe artichoke TPC (Lombardo et al., 2017b, 2022; Pandino et al., 2022a, b; Salata et al., 2022). Among the studied ecotypes, 'Santa Domenica Vittoria' reached the highest TPC in both the receptacle and floral stem. 'Monterosso Almo' also reported one of the highest TPC in the receptacle, while 'Bellocozzo' and 'Quartarella' reported the lowest values. 'Caltagirone' and 'Domestica di Castelvetrano', with 'Monterosso Almo', had the highest TPC in the floral stem (Figure 2). It is interesting since the floral stem, if properly prepared, is fully edible as the receptacle. The TPC in the bracts was almost stable, varying from 15.8 ('S. Giacomo 1') to 24.2 g kg^{-1} DM ('Santa Domenica Vittoria') (Figure 2). Of the ecotypes, 'Spinoso di Sciara' also achieved the highest TPC in the bracts, together with 'Santa Domenica Vittoria' (Figure 2). This is relevant since bracts – a consistent part of the wastes resulting from globe artichoke processing – can be valorised by extraction of these natural antioxidants. Our data confirmed the observed trend of TPC accumulation in the capitulum fractions already observed in the literature (Pandino et al., 2012b; Lombardo et al., 2022).

A high variability among the examined ecotypes was noted for the AsAc in the receptacle (Figure 3). The richest ecotype was 'Chiaramonte inerme', followed by 'Naro 3', 'Quartarella' and 'Naro 4', while the poorest were 'Chiaramonte spinoso', 'S. Giacomo 3' and 'Donnafufgata'.

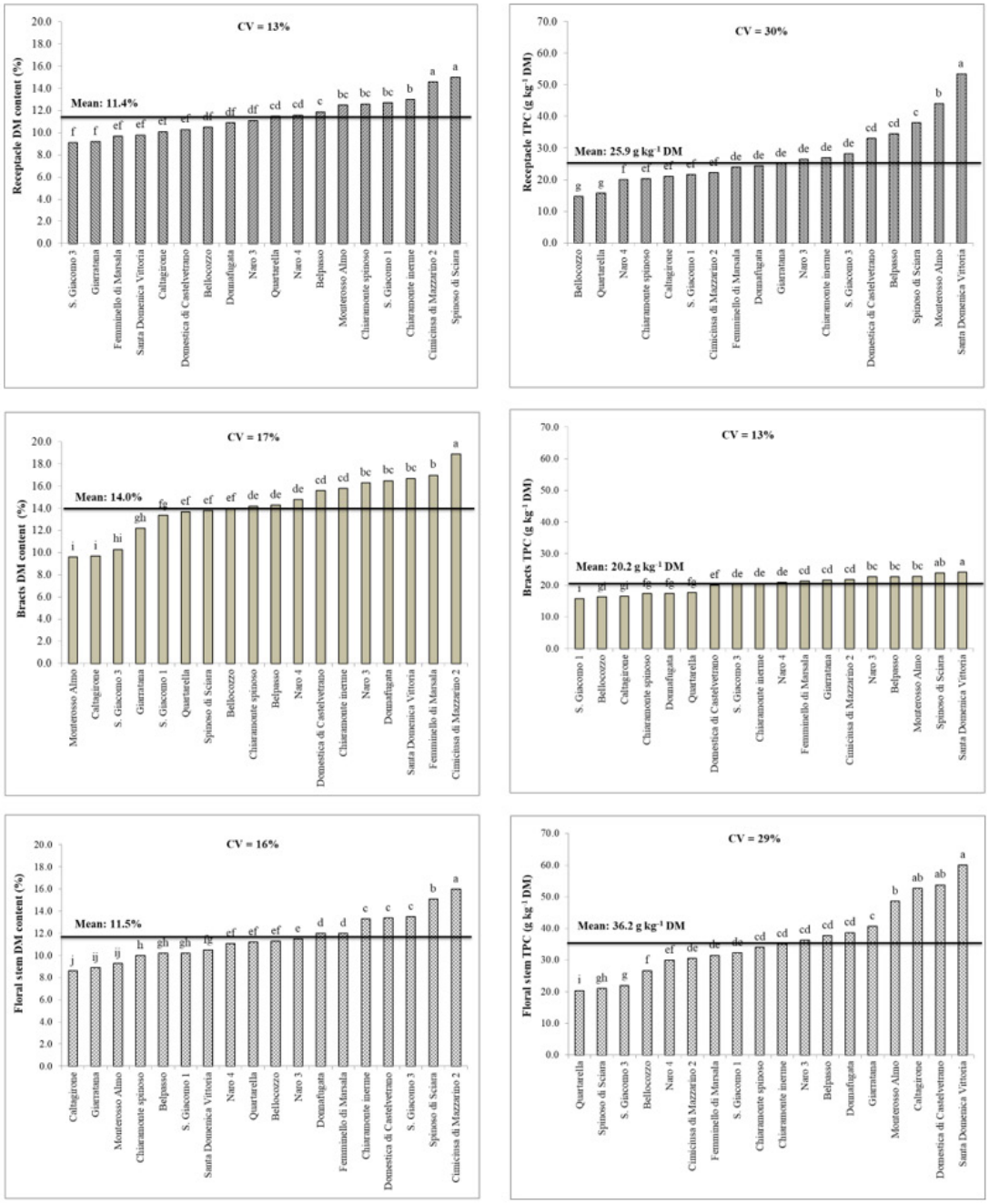

Figure 2. Dry matter (DM) and total polyphenol content (TPC) in the receptacle, bracts and floral stem. Different letters within each parameter indicate statistically differences among means (Tukey's HSD, $P \leq 0.05$). The horizontal black lines indicate the global mean per each trait.

Both receptacles' cutting resistance and total color change significantly differed among the studied ecotypes (Figure 4). 'Monterosso Almo' and 'Spinoso di Sciara' exhibited the highest resistance after cutting, while 'S. Giacomo 1' the lowest value. This parameter may be important as an index for evaluating the texture (crunchiness) of fresh-cut products. Color changes after cutting of receptacles unequivocally occur as a consequence of enzymatic browning phenomena (Pandino et al., 2017; Rizzo et al., 2019, 2021). In this case, lowest the value of ΔE better the result in terms of the possible processability of each ecotype as a fresh-

cut product. In this view, 'Bellocozzo', 'Donnafugata', 'Belpasso' and 'Chiaramonte inerme' featured well in virtue of values ranging from 3.1 to 4.0. On the contrary, a high ΔE was observed for 'S. Giacomo 1', 'Cimiciusa di Mazzarino 2' and 'Chiaramonte spinoso' (8.4, on average; Figure 4).

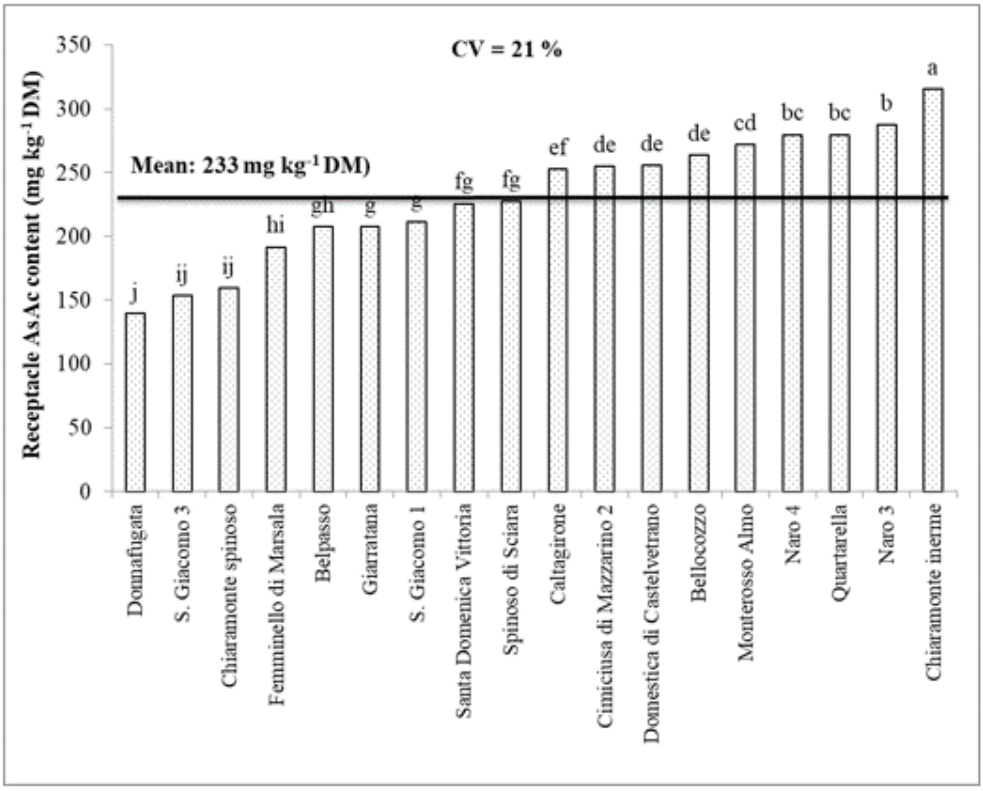

Figure 3. Ascorbic acid (AsAc) content in the receptacle of the studied ecotypes. Different letters indicate statistically differences among means (Tukey's HSD, $P \leq 0.05$). The horizontal black line indicate the global mean.

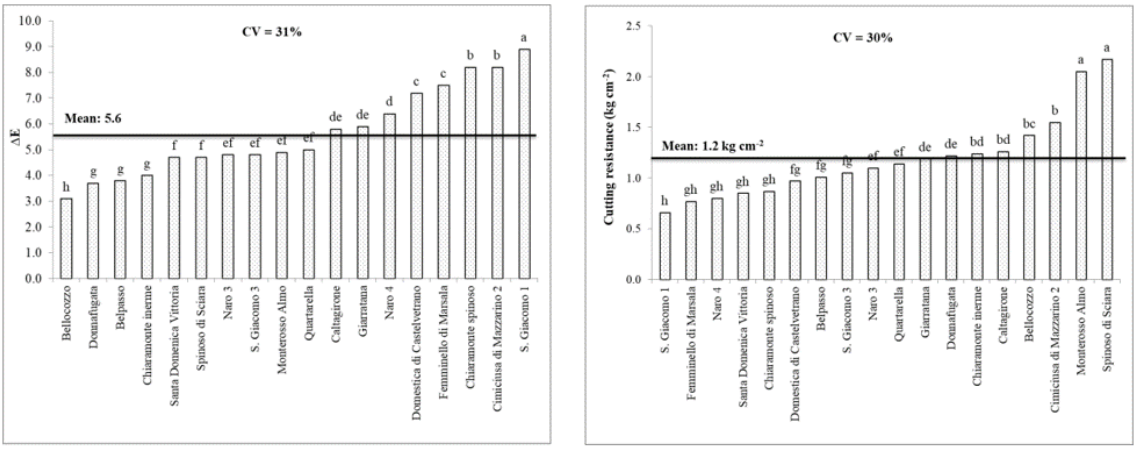

Figure 4. Total color difference (ΔE) and cutting resistance of the receptacle of the studied ecotypes. Different letters indicate statistically differences among means (Tukey's HSD, $P \leq 0.05$).The horizontal black lines indicate the global mean per each qualitative trait.

CONCLUSIONS

The potential of the globe artichoke biodiversity in the Mediterranean area is enormous but at risk of genetic erosion, because only a limited number of varieties are vegetatively propagated and grown. In facing the challenges of modern agriculture to improve crop diversification at a market level, the results acquired highlighted that the considered morphological (capitulum fresh weight and receptacle incidence) and qualitative characteristics were able to distinguish the globe artichoke ecotypes by diversifying them for specific end-uses. Although the major part of ecotypes still remain neglected and unnoticed due to their restricted area of cultivation and low yield, the importance to preserve them as a resource for broadening the genetic base of globe artichoke is indisputable as novel source of relevant qualitative traits, as well as of disease resistance and tolerance to abiotic stresses.

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