Productive and morphological characterization of new Sicilian seed-grown hybrids of globe artichoke

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Abstract

The first Italian region for globe artichoke production is Sicily, where, nevertheless, its cultivation is still anchored mainly to traditional and irrational practices such as vegetative propagation. The latter has disadvantages, such as the heterogeneity of the propagation material and the transmission of diseases from mother plants. Conversely, propagation by achene, improperly called "seed", would contribute to the rationalization of the cultivation technique, the improvement of the phytosanitary state of the plants and the increase in yields. In Sicily there are some globe artichoke districts, i.e. places where the cultivation of the globe artichoke takes on an important economic and social significance. These districts fall within western Sicily, where 'Spinoso di Palermo' is traditionally grown, and in eastern Sicily, where 'Violetto di Sicilia' is traditionally cultivated. In the present work, four seed-grown F_1 hybrids ('Green bell', 'Nap 5', 'Zenone' and 'Ernesto') selected by a Sicilian seed company were compared with autochthonous genotypes traditionally propagated by vegetative means, in two different locations: Caccamo (western Sicily) and Pachino (southeastern Sicily). The Sicilian F_1 hybrids studied in this work were characterized from a morphological and productive point of view for the first time, thus giving a new contribution of knowledge on globe artichoke biodiversity. The most productive hybrid tested in Caccamo was 'Ernesto' with 22.5 t ha^{-1} of fresh capitula, followed by 'Green bell' and 'Nap 5' (18.7 and 17.8 t ha^{-1}, respectively), while 'Zenone' achieved 14.0 t ha^{-1}. The most productive genotype tested in Pachino was by far 'Green bell', with 25.0 t ha^{-1} of fresh capitula, followed by 'Nap 5' and 'Zenone', with 13.3 and 12.7 t ha^{-1} respectively. The least productive genotypes were the vegetatively propagated ones, namely 'Spinoso di Palermo' (in Caccamo), with 5.6 t ha^{-1}, and 'Violetto di Sicilia' (in Pachino), with 9.2 t ha^{-1}.

Keywords: globe artichoke, F_1 hybrids, seed propagation, yields, Sicily

INTRODUCTION

Globe artichoke [*Cynara cardunculus* L. var. *scolymus* (L.) Fiori] is an herbaceous plant, native to the Mediterranean basin, very rich in secondary metabolites (mainly polyphenols and sesquiterpene lactones) with different biological activities (Lombardo et al., 2022; Pandino et al., 2022). Italy is the main producing country in the world (Faostat, 2023) and, according to ISTAT (2023), in the three-year period 2020-2022, the total Italian harvested areas amounted to 38,260 ha, while the harvested production amounted to 373,822 tons. Sicily is currently the main Italian globe artichoke producing region, with 40% of the national harvested areas and 41% of the productions (ISTAT, 2023). For this reason, globe artichoke gives an important contribution to Sicilian agricultural economy (Pandino et al., 2011; Portis et al., 2012). However, production costs are rising, as well as competition with other countries. In such a situation, diversifying the product, that is growing new varieties at an affordable price, is one of the ways Sicilian globe artichoke growers can increase their profit margins (Sgroi et al., 2015). On the other hand, there are technical needs of globe artichoke cultivation in Sicily that can only be satisfied through the introduction of process and product

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innovations. Among these needs is the rationalization of the method of propagation of the Sicilian globe artichoke varieties. The propagation of the globe artichoke is traditionally carried out in Sicily by vegetative means. This method has disadvantages, such as the heterogeneity of the propagation material, the transmission of diseases from the mother plants, high cost of plantation and high percentage of planting failures (Mauromicale et al., 2018; Mazzeo et al., 2020). Propagation by achene, improperly called "seed", on the other hand would contribute to the rationalization of the cultivation technique, to the improvement of the phytosanitary status of the plants and to the increase in yields (Mauromicale et al., 2018; Mauromicale and Ierna, 1995). In Sicily there are some globe artichoke districts, namely areas traditionally devoted to the cultivation of the globe artichoke, where it is of particular importance from an economic and social point of view. In the districts of western Sicily, the 'Spinoso di Palermo' is traditionally grown, while in the districts of eastern Sicily the 'Violetto di Sicilia' is traditionally cultivated (Pandino et al., 2012). However, seed-propagated cultivars are still low adopted in Sicily. In the present work, four seed-grown F_1 hybrids selected by a Sicilian seed company were compared with varieties traditionally propagated by vegetative means, in two different locations: the one in western Sicily, where globe artichoke has a great tradition, and the other in southeastern Sicily, where the interest in the globe artichoke is growing. The Sicilian F_1 hybrids studied in this work were characterized from a morphological and productive point of view for the first time, thus giving a new contribution of knowledge on the varietal panorama of the globe artichoke.

MATERIALS AND METHODS

Site and soil

The field trials were carried out in two different locations (Figure 1): the one near Caccamo (western Sicily), in Eutric Regosol (USDA, 2017) with sandy clay loam texture, and the other one in Pachino (southeastern Sicily) in Eutric Cambisol (USDA, 2017) with sandy loam texture.

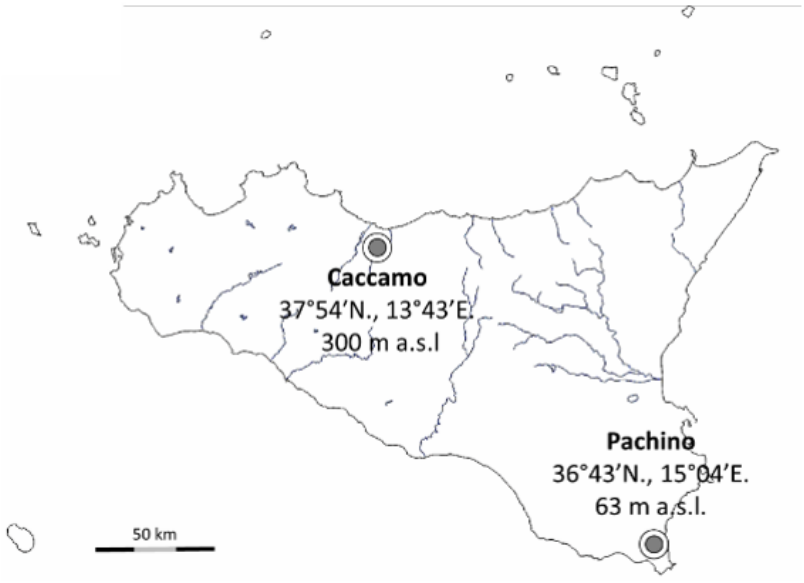

Figure 1. Locations of the two experimental field.

The local climate is characterized by mild, wet winters and hot, dry summers. According to Bagnouls and Gaussen (1957) classification, the local climate is thermomediterranean. The Peguy diagrams (Figures 2 and 3) show the rainy and the dry months of both the long period and the 2021-2022 period. The polygons depicting the long-term trend in both Caccamo

(Figure 2A) and Pachino (Figure 3A) are elongated in the direction of the horizontal axis and represents a climatic condition characterized by high annual temperature ranges. The climatic conditions of Caccamo are characterized by a higher annual rainfall than Pachino (705 vs. 511 mm), (SIAS, 2023). The rainiest months in Caccamo are from October to March, when about 75% of the annual rain is concentrated, while more than 80% of the rain that falls on Pachino is concentrated in the months from September to February (SIAS, 2023). The average annual temperature in Caccamo is lower than that of Pachino (16.7 vs. 18.4), (SIAS, 2023). The hottest month in Caccamo is August (24.9°C), while the coldest is January (9.7°C) (SIAS, 2023). The hottest month in Pachino is August (26.6°C), while the coldest one is February (11.6°C) (SIAS, 2023). Altogether, this has as a result that in Caccamo there are four dry months (from May to August), while in Pachino there are five (from April to August) (Figures 2A and 3A).

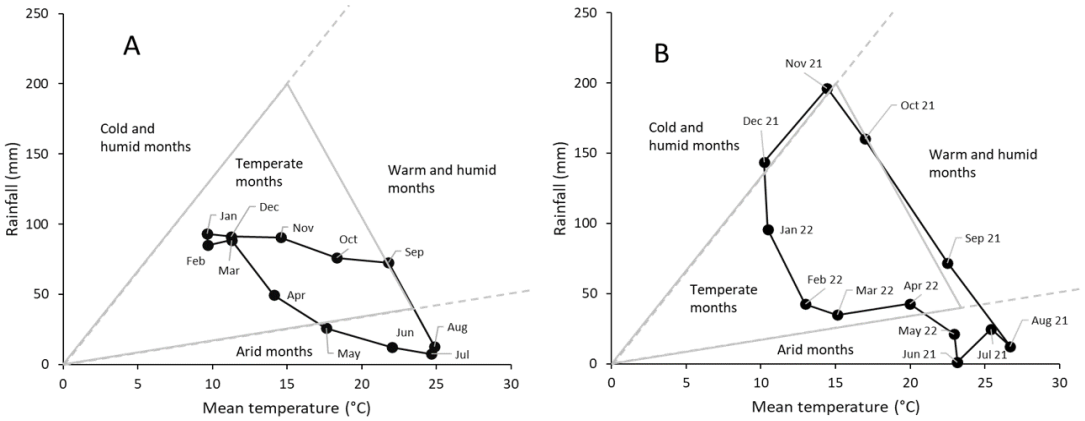

Figure 2. Peguy diagrams of mean monthly temperature and monthly precipitation in the long term period (2002-2022) (A) and in the trial period (B) in Caccamo.

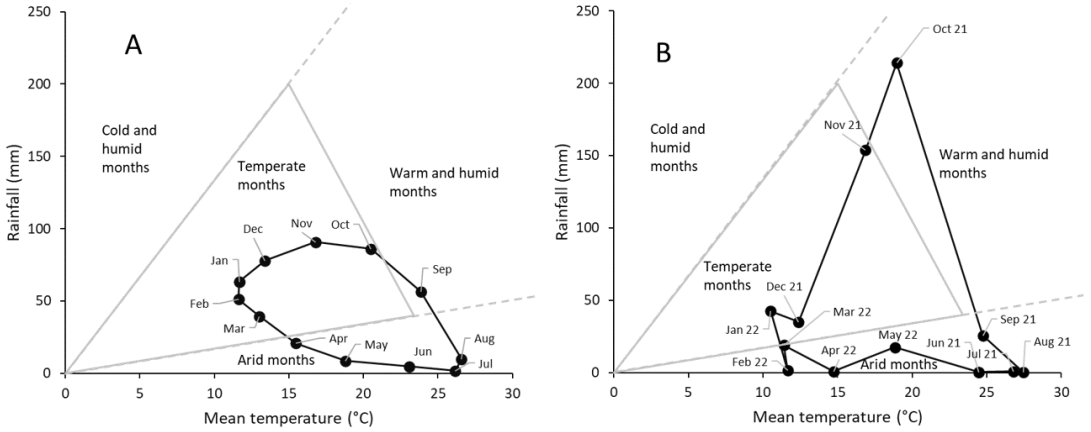

Figure 3. Peguy diagrams of mean monthly temperature and monthly precipitation in the long term period (2002-2022) (A) and in the trial period (B) in Pachino.

Meteorological conditions during the trial period

At both locations, trials took place from the last week of July 2021 to the first week of May 2022. In Caccamo, precipitation in the 2021-2022 season was higher than the long-term mean (848 vs. 705 mm) (Figure 2B) (SIAS, 2023). The polygon that describes the temperature and rain trend in Caccamo for the 2021-2022 season is very irregular, and shows that October, November, and December were extraordinarily rainy (Figure 2B) (SIAS, 2023). Furthermore, from February until the end of the cycle, average temperatures were well above their long-

term averages (Figure 2B) (SIAS, 2023). The rainfall in Pachino during the 2021-2022 season is equal to the long-term average (511 mm), but it is evident that its distribution is extremely irregular (Figure 3B). The extraordinary rainfall of the months of October and November 2021 (SIAS, 2023), which culminated in a Mediterranean tropical-like cyclone between 24 October and 2 November 2021, contrasts dramatically with the seven dry months, including February and March, which are normally temperate months (Figure 3B). For the rest, the average monthly temperatures recorded in the 2021-2022 year are in line with the long-term monthly averages (SIAS, 2023) (Figure 3B).

Plant material and crop management

Three seed propagated F_1 hybrids, namely 'Green bell', 'Nap 5', and 'Zenone' were compared at both locations. 'Green bell' is a genotype attributable to the 'Romaneschi' typology, while 'Zenone' and 'Nap 5' belong to the 'Violetti' typology (Table 1). In Caccamo a further seed propagated genotype was tested, 'Ernesto', which, being spiny, is of particular interest in western Sicily (Table 1). In the field set up in Caccamo, these genotypes propagated by seed were compared with the 'Spinoso di Palermo', propagated vegetatively (i.e. "ovoli"), belonging to the 'Spinosi' group and typical of western Sicily (Table 1). In the Pachino field, on the other hand, the hybrids were compared with the 'Violetto di Sicilia', also propagated by vegetative means, but belonging to the 'Catanesi' group and traditionally cultivated in eastern Sicily (Table 1).

Table 1. Capitula shape of the genotypes under study.

Genotype	Nap 5	Green bell	Zenone	Ernesto	Violetto di Sicilia	Spinoso di Palermo
Shape						

Comparisons with traditional local varieties propagated by vegetative means were carried out in order to evaluate how Sicilian globe artichoke cultivation can be modernized also through the introduction of new seed-propagated varieties. The tests were conducted in real field conditions and in the framework of a reciprocity of interactions between researchers and farmers. These features gave this study the connotation of On Farm Experimentation (OFE). The trials were set out in two randomized blocks, each of which was about 600 m^2, with six replications per genotype. Prior to planting, the field was ploughed to a depth of ~30 cm, and then harrowed. In both locations, the seedlings and "ovoli" were transplanted at the end of July, at a rate of 1.12 plants m^{-2}, using an inter- and intra-row spacing of, respectively, 1.4 and 0.8 m. Fertilization was provided based on soil analysis and crop requirements, namely: 100 kg ha^{-1} of P_2O_5 (as single superphosphate) 150 kg ha^{-1} of K_2O (as potassium sulfate). Finally, 210 kg of nitrogen ha^{-1} were supplied with fertigation in 5 fractions at times agreed with the farmers (in an OFE perspective). Three treatments with gibberellic acid (40 ppm) were given: the first at the phenological stage of 12 fully open leaves, the second 15 days after the first, and the third 15 days after the second. In both locations, irrigation was provided from transplant until mid-October (Figure 4), considering the reference evapotranspiration and the crop coefficient (Boari et al., 2000), which varies during the phenological phases. Also considering the farmers' indications (in an OFE framework), the seasonal volume of water supplied with irrigation in Caccamo was about 1800 m^3 ha, while in Pachino about 2400 m^3 were provided.

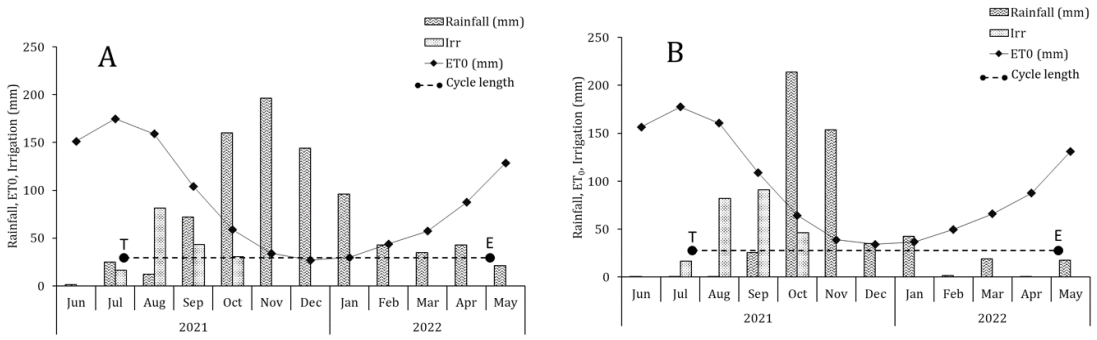

Figure 4. ET_0 vs. rainfall + irrigation in Caccamo (A) and in Pachino (B). T = transplant; E = end of cultivation cycle.

Statistical analysis

All data were subjected to an analysis of variance (ANOVA) and the means for each trait were separated by Fisher's least significance difference test, applying a threshold of 0.05.

RESULTS AND DISCUSSION

Overview

The following pages will present the morphological characterization of the capitula collected from the different genotypes. Furthermore, the yields per hectare of each genotype in relation to the location are shown.

Research data

1. Capitula weight and their morphological characterization in the two locations.

In Caccamo, the genotype whose capitula showed the greatest average weight was 'Nap 5', with 161 g, followed by 'Green bell' with 142 g (Table 2). Capitula belonging to 'Ernesto' and 'Zenone' reached almost the same average weight (129 and 127 g, respectively), while 'Spinoso di Palermo' produced the smallest capitula in Caccamo, with a mean weight of 100 g (Table 2). In Pachino, 'Green bell' produced the largest capitula (214 g on average), 'Nap 5' and 'Zenone' followed with 179 and 177 g, respectively, while 'Violetto di Sicilia' produced on average the smallest capitula (149 g) in Pachino (Table 3). On average, the receptacle weight represented a percentage between 15 and 17% of the total capitulum weight in the F_1 hybrids, but it was considerably higher in the traditional genotypes (Tables 2 and 3). Moving from the weight to the number of capitula, the most productive genotype in Caccamo was 'Ernesto', with an average of 19.5 capitula per plant, 'Green bell' produced 14.7 capitula per plant, while 'Nap 5' and 'Zenone' produced the same number of capitula (12.4) (Table 2). The lowest number of capitula per plant in Caccamo was found on 'Spinoso di Palermo' (6.3) (Table 2). In Pachino 'Green bell' produced on average 13.1 capitula per plant, 'Nap 5' and 'Zenone' followed with 8.3 and 8.1, respectively, while 'Violetto di Sicilia' produced a mean of 6.9 capitula per plant (Table 3). The capitula of all the genotypes under study have an elongated shape, except those of 'Green bell', which are enlarged, having a ratio between the longitudinal diameter and the transversal diameter of 0.9 (Tables 2 and 3). Based on the morphological characteristics of the capitulum, it is possible to establish the intended use of each genotype. 'Green bell' can be included in the 'Romaneschi' group, with the relative use. 'Zenone' and 'Nap 5', with purple bracts, are suitable for fresh consumption in Italy, while 'Ernesto', whose capitula are spiny and relatively small, could be destined for industrial processing.

Table 2. Capitula characteristics and yields of the genotypes tested in Caccamo location.

Genotype	Capitula fresh weight (g)					Rec (%)	L d (cm)	T d (cm)	L/T	No. of capitula plant^{-1}	Yield as fresh capitula (t ha^{-1})
	Main	1st order	2nd order	3rd order	Average						
Nap 5	231 a	175 a	151 a	120 a	161 a	17 b	7.8 b	7.1 a	1.1	12.4 c	17.8 b
Green bell	228 a	162 b	133 b	118 a	142 b	15 b	6.6 c	7.1 a	0.9	14.7 b	18.7 b
Zenone	214 b	139 c	113 c	109 b	127 c	17 b	8.1 b	6.5 b	1.3	12.4 c	14.0 c
Ernesto	197 c	138 c	132 b	115 ab	129 c	16 b	8.5 b	7.4 a	1.2	19.5 a	22.5 a
Spinoso di Palermo	154 d	115 d	96 d	36 c	100 d	27 a	11.1 a	6.2 b	1.8	6.3 d	5.6 d

Rrec (%) = average percentage incidence of the receptacle weight on the whole capitulum; L d = longitudinal diameter of capitula; T d = transverse diameter of capitula; L/T = ratio between longitudinal diameter and transversal diameter of capitula.

Different small letters within each column indicate significance at LSD test (P≤0.05).

Table 3. Capitula characteristics and yields of the genotypes tested in Pachino location.

Genotype	Capitula fresh weight (g)					Rec (%)	L d (cm)	T d (cm)	L/T	No. of capitula plant^{-1}	Yield as fresh capitula (t ha^{-1})
	Main	1st order	2nd order	3rd order	Average						
Nap 5	254 c	204 b	153 b	130 b	179 b	17	8.7 a	7.6 b	1.1	8.3 b	13.3 b
Green bell	436 a	218 a	196 a	163 a	214 a	17	7.5 b	8.3 a	0.9	13.1 a	25.0 a
Zenone	285 b	227 a	122 c	113 c	177 b	15	9.1 a	7.5 b	1.2	8.1 b	12.7 b
Violetto di Sicilia	199 d	170 c	116 c	107 c	149 c	24	8.6 a	6.9 c	1.2	6.9 c	9.2 c

Rec (%) = average percentage incidence of the receptacle weight on the whole capitulum; L d = longitudinal diameter of capitula; T d = transverse diameter of capitula; L/T = ratio between longitudinal diameter and transversal diameter of capitula.

Different small letters within each column indicate significance at LSD test (P≤0.05).

2. Yields in fresh capitula in the two locations.

In Caccamo, the genotype that yielded the most in terms of fresh capitula ha^{-1} was 'Ernesto' with 22.5 t ha^{-1} (Table 2). 'Green bell' and 'Nap 5' follow with 18.7 and 17.8 t ha^{-1}, respectively (Table 2). 'Zenone' produced 14.0 t ha^{-1}, while 'Spinoso di Palermo' was by far the least productive genotype with 5.6 t ha^{-1} (Table 2). Moving on to consider Pachino, 'Green bell' was by far the most productive genotype, with 25.0 t ha^{-1} of fresh capitula, while 'Nap 5' and 'Zenone' produced lesser quantities, namely 13.3 and 12.7 t ha^{-1}, respectively (Table 3). 'Violetto di Sicilia' was the least productive of the genotypes cultivated in Pachino (9.2 t ha^{-1}) (Table 3). In both locations, the seed-propagated genotypes were far more productive than the vegetatively propagated genotypes. Looking at Tables 2 and 3 simultaneously, it emerges that the yields of 'Green bell' and 'Nap 5' vary differently depending on the location. An extremely significant "Genotype" × "Location" interaction emerged from the two-way ANOVA ($p<0.001$).

CONCLUSIONS

Based on the morphological characteristics of the capitula, an evaluation of the use of the new genotypes is possible. 'Green bell' has an enlarged capitulum and can be included in the group of 'Romaneschi', with the relative use. 'Nap 5' and 'Zenone', having purple bracts, are indicated for fresh consumption in Italy. 'Ernesto', being spiny and having relatively small capitula, could be suitable for industrial processing. The F_1 hybrids propagated by "seed" showed to be more productive than the traditional vegetatively propagated Sicilian varieties. The pedoclimatic conditions of the locations produced different effects on the yields of the 'Green bell' and 'Nap 5' genotypes. Pachino enhanced the yields of 'Green bell', while in Caccamo 'Nap 5' produced more than in Pachino.

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