Distribution and major morphological traits of wild asparagus (*A. acutifolius* L. and *A. albus* L.) in Sicily

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Abstract

***Asparagus acutifolius* L. and *Asparagus albus* L. are among the most widespread wild species throughout the Mediterranean basin. In Italy, they find especially favourable growth conditions in the central and southern regions of the peninsula and in the major islands, where they have been used since ancient times for food and medicinal purposes. In view of the high potential interest of wild asparagus for cropping and marketing purposes, numerous botanical surveys were carried out in different Sicilian sites, to determine the presence of these species in natural stands. Small samples of seeds and/or propagation material were taken for each ecotype, further inserted in a collection field for evaluation and ex situ conservation. The main morphological and physiological traits were collected, including number of stems per crown, canopy height, transverse and longitudinal canopy diameter, flowering and fruiting period, and 1000 seed weight. The obtained data were submitted to multivariate statistical analysis. The results showed that morphological characteristics are a suitable tool to discriminate between wild asparagus populations for the evaluation of genetic diversity within a semi-arid Mediterranean area such as Sicily.**

Keywords: *Asparagus acutifolius*, *Asparagus albus*, wild species, Mediterranean environment, biodiversity in agriculture

INTRODUCTION

The Mediterranean basin is characterized by the presence of countless wild edible species. They usually constitute an indispensable component of people's diets around the world (Ferrara et al., 2011). Attention to these plants comes from their rediscovered use in local cuisine, biodiversity protection systems, and their agronomic potential as new crops (Pieroni et al., 2005). The *Asparagus* genus, belonging to the *Asparagaceae* family, falls into this group of important Mediterranean wild food plants; it includes over 250 species, valuable in both the food and medical sectors (Bozzini, 1959). Nowadays, *Asparagus officinalis* L. is the only cultivated asparagus, while *Asparagus acutifolius* L. and *Asparagus albus* L., are two of the most diffused wild species that are edible and traditionally consumed (Venezia et al., 1993).

A. acutifolius is an herbaceous, evergreen perennial, and dioecious species that is widely distributed in Mediterranean countries of Europe, North Africa, and West Asia. It is green with a short rhizome, the spears are small (about 4-6 mm in diameter) and sweet or slightly bitter, greenish, and elongated (Boubetra et al., 2017). The mature vegetation is somewhat prickly. Fruits of the female plants are globose and green berries that turn black when ripe; they have 1-2 seeds, which have strong dormancy and are difficult to germinate (Katsenios et al., 2019). *Asparagus albus* L., on the other hand, is a hermaphroditic species that presents a large, much branched rhizome. Shoots are pinkish-white, then green, 5-15 mm in diameter, and they are characterized by a sweet flavor. Leaves are converted to stout, woody, white, prickly thorns. Berry when ripe, presents bright red exocarp (later black), and reddish endocarp, spherical, rounded at apex; they are 4-6 mm in diameter, usually monospermous and deciduous. As in the case of *A. acutifolius*, seeds are typically spherical (or hemispherical), black, 3-4 mm in diameter, and 1-2 in number per berry (Bozzini, 1959).

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Both species are very similar as concerns their biological cycle. The shoots appear in spring and differentiate rapidly. Flowers appear in August-October (Boubetra et al., 2017) and berries ripen in winter (from November to December); fruits are dispersed by birds (Tirado and Pugnaire, 2003).

They are typical of Mediterranean shrublands (maquis), and can be found in abandoned land and ruderal places. *Asparagus albus* typically grows in arid places of coastal areas, where it sometimes creates dense low and impenetrable brambles (Bozzini, 1959). It is associated with dry lands, rocky soils, and cliffs of subhumid and semi-arid bioclimates, in plant communities also including *Ruscus hypophyllum*, *Calycotome spinosa* and *Opuntia ficus-indica* (Boubetra et al., 2017). *Asparagus acutifolius* is a relatively ubiquitous species in central-southern Italy, even if it prefers sunny and warm localities (Bozzini, 1959).

These two wild species could become promising new niche crops, especially for marginal rural areas, prone to be abandoned due to a lack of sufficient income from agriculture (Ferrara et al., 2011), for different reasons:

- Their relatively high productivity (Rosati and Falavigna, 2000; Benincasa et al., 2007), their high disease and pest resistance, as well as their ability to easily grow under organic farming conditions;
- Their significant nutraceutical value. *A. acutifolius* shoots have been found to possess a high content of antioxidants, such as vitamins (B9 and E), phenols and carotenoids, and also, linoleic and essential n-6 fatty acids (Martins et al., 2011; García-Herrera et al., 2013; Sánchez-Mata et al., 2016). All these compounds make the consumption of wild asparagus advantageous to human health given their protective or disease preventive properties (Di Maro et al., 2013);
- Their medicinal properties, related to the presence of steroidal saponins and sapogenins in various plant parts (Ferrara et al., 2011; Sautour et al., 2007). For instance, a decoction is used as a diuretic (Maccioni et al., 2004);
- Their distinctiveness and their long-recognized value in culinary and folk tradition history. The edible spears are mainly gathered from wild plants since ancient times (Katsenios et al., 2019) and their use for domestic dishes, such as omelettes, sauces, risotto, or even eaten raw in mixed salads, is consolidated (Arcidiacono and Pavone, 1994);
- The recent and important growing demand from consumers for wild asparagus spears, mainly due to their important nutritional value, and their relatively high prices in local markets (Ferrara et al., 2011; Rosati, 2001; Venezia et al., 1993; Pieroni et al., 2005; Della et al., 2006; Molina et al., 2012);
- The recently studied possibility of including these crops in articulated agroforestry systems (Rosati et al., 2012).

For all these reasons, interest in the cultivation of wild asparagus has grown, and stimulated research on it. However, there is very little information to date involving suitable cultivation techniques (Benincasa et al., 2007).

Hence, the aim of the present work was the implementation of a survey on *Asparagus acutifolius* and *A. albus* distribution in Sicily, to develop an ecological framework that could be the basis for further studies. A preliminary study on the morphological and physiological characterization of the collected accessions was also conducted, in order to isolate the best genotypes suitable to cultivation in a semi-arid Mediterranean area such as Sicily.

MATERIALS AND METHODS

The research work was structured in two main phases: initially, an ecological survey was developed about the regional distribution of the two species of *Asparagus*, followed by a collection program; then a cultivation plan was implemented to create a collection field, with previously gathered accessions, to characterize them morphologically and physiologically.

The field was set up at the experimental farm Don Pietro Canicarao, situated about 6.5 km from Comiso (RG) in south-eastern Sicily (36°58'51.0"N, 14°38'36.5"E, 220 m a.s.l.). The location is characterized by a warm temperate climate according to the Köppen-Geiger classification, with dry summers (Csa). The average annual rainfall is approximately 541 mm,

mainly distributed in autumn (34%) and winter (43%). The annual average temperature is 16.45°C, the average maximum temperature is 20.05°C, and the average minimum temperature is 13.01°C. The soil type in the area is mostly clay (40% clay, 35% silt, and 25% sand), classified as Pachic Calcixerolls (United States Science and Education Administration, 1975). The soil chemical characteristics (0-40 cm) were pH 8.0 (1:2 H_2O); total carbon, 1.73% (Walkley Black method); and total nitrogen, 1.75‰ (Kijeldhal method).

Ecological survey

The gathering campaign began in November 2003, the period of full fructification, and it ended in mid-January of the following year.

At this stage, the focus was on ecological and chorological characters; where the edaphic, altitudinal, bioclimatic, vegetation features, and the distribution range, were investigated. To achieve the highest possible grade of genetic diversity, collections were carried out by taking seed samples in each of the 13 stations (Table 1; Figure 1), which were located at different altitudes (mountains, hills, coast) and characterized by different substrates (limestone, calcarenites, clays, arenites, vulcanites, etc.) and environments (Mediterranean scrub, woods, garrigue, etc.). Surveys for each location also included photographic support. At the end of the collection campaign, 8 seed samples of *Asparagus acutifolius* and 5 of *Asparagus albus* were collected.

Table 1. List of *Asparagus acutifolius* and *A. albus* populations collected.

ID[a]	Collection date	Origin[b]	Coordinates	Station
Ac-MP	18/12/2003	Pollina (PA)	37°59'41.1"N 14°09'20.1"E	Parco delle Madonie
Ac-RP	22/12/2003	Pachino (SR)	36°41'08.9"N 15°03'24.7"E	Rio Pantani
Ac-CO	23/12/2003	Comiso (RG)	36°56'44.4"N 14°38'11.9"E	Monti Iblei
Ac-OS	29/12/2003	Agnone (SR)	37°19'25.7"N 15°05'15.3"E	RNO Oasi del Simeto
Ac-CS	30/12/2003	Castiglione di Sicilia (CT)	37°51'05.0"N 15°05'02.1"E	Parco dell'Etna
Ac-ER	15/12/2003	Erice (TP)	38°02'32.3"N 12°35'57.5"E	Montagna Grande
Ac-CR	15/1/2004	Terrasini (PA)	38°08'13.2"N 13°03'24.3"E	RNO Capo Rama
Ac-FC	17/12/2003	Godrano (PA)	37°53'26.3"N 13°24'47.5"E	RNO Bosco della Ficuzza C/ da Casale
Al-DC	21/12/2003	Bivona (AG)	37°35'28.4"N 13°24'10.2"E	Diga Castello
Al-SS	21/12/2003	S.Stefano Quisquina (AG)	37°32'33.1"N 13°30'56.7"E	Az. Pietranera
Al-CP	22/12/2003	Porto Palo di C. Passero (SR)	36°40'56.5"N 15°07'17.9"E	Capo Passero
Al-VF	17/12/2003	Altofonte (PA)	38°02'17.8"N 13°19'50.1"E	Valle del Fico
Al-Mo	25/11/2003	San Biagio Platani (AG)	37°33'55.4"N 13°31'57.4"E	Molinazzo

[a] Ac: *Asparagus acutifolius*, and Al: *Asparagus albus*.

[b] Between parentheses indicates the province of origin, PA: Palermo, SR: Siracusa, RG: Ragusa, CT: Catania, TP: Trapani, AG: Agigento.

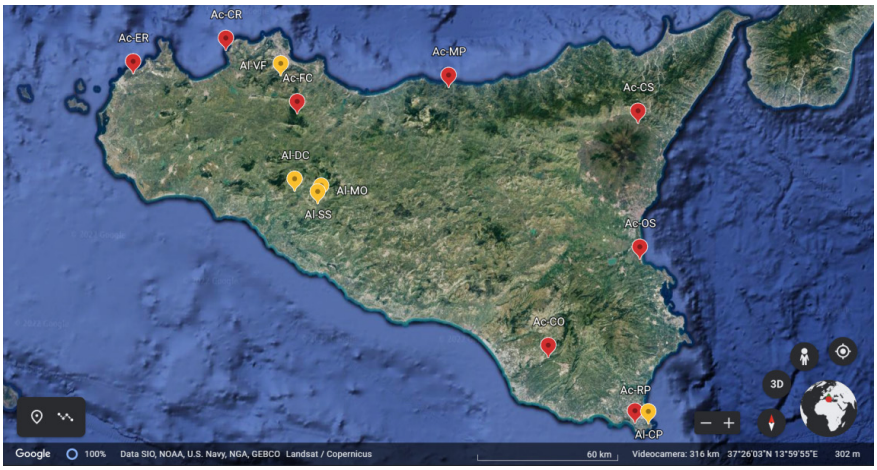

Figure 1. Collection sites of *Asparagus acutifolius* (red pins) and *Asparagus albus* (yellow pins) samples studied in this work.

Morphological and physiological characterization

The collected plant material was initially placed in seedbeds and then in plastic pots for a 6-month period, to reach a growth stage suitable for field transplanting. In the collection field the soil had been previously tilled, but not fertilized. The 6-month-old plantlets were transplanted in late summer 2006, adopting a spacing of 1.30 m between rows and 0.30 m between plants within a row (about 25,000 plants ha^{-1}); the chosen experimental layout was a complete randomized block design (CRBD) with four replications.

During the growing season, the following morphological traits were measured: number of stems $plant^{-1}$, plant height (five measurements for each plot, both of unmodified canopy and of stretched plant height; cm), longitudinal and transverse plant diameter (cm), rate of flowering/fruiting (presence/absence of flowers and fruits in each plant, respectively), presence/absence of shoots. In addition, the weight of 1000 seeds of each accession was measured in the laboratory.

Furthermore, with the goal to compare the overall growth of plants throughout the observation period, the plant canopy volume (cm^3) was estimated. Assuming that the individual plant takes the shape of an inverted cone, as stated by visual assessment of usual growth behaviour in isolated plants, the volume was calculated using the following formula: $V = (\pi r^2 h)/3$, where r was the average of the two plant diameters divided by 2, and h was the unmodified canopy height) (Figure 2).

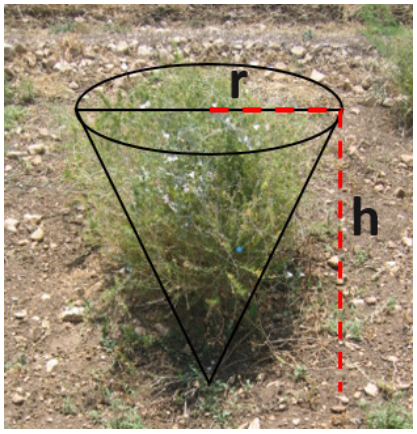

Figure 2. Plant of *Asparagus acutifolius* with details of the inverted cone shape assumed to estimate plant volume.

All collected morphological and physiological data were first ordered and then submitted to statistical analysis by means of the statistical package Minitab® v 17.1.0. to detect any pattern within- and among-population variability.

For each measured trait, the maximum and mean values were taken into account, therefore including maximum and mean number of stems plant^{-1}, maximum and mean canopy (unmodified) height, maximum and mean stretched height, maximum and mean longitudinal and transverse diameter, maximum and mean estimated plant volume.

Furthermore, physiological data included maximum flowering percentage, number of days to 50% flowering, maximum fructification percentage, number of days to 30% of fructification, maximum percentage presence of spears, and number of days to 50% of presence of spears.

RESULTS AND DISCUSSION

Ecological survey

The survey and collection activity showed that *Asparagus acutifolius* is characterized by a very large value at the edaphic, bioclimatic, and vegetation levels. Concerning the edaphic level no preference was found, as it is equally present on sandy, rocky and clay substrates of evaporitic, volcanic, or metamorphic nature. Regarding the altitude, the entity extends from sea level to an altitude of about 1100 m a.s.l. Concerning bioclimatic framing, the species is distributed from the infra-Mediterranean semi-arid plane (characterized by temperatures above 18°C and rainfall lower than 350 mm year^{-1}) of the Pelagian Islands to the upper subhumid meso-Mediterranean (defined by temperatures between 13 and 16°C and rainfall lower than 1000 mm year^{-1}) of the highest areas of the main Sicilian Mountain ranges (Madonie, Nebrodi, Peloritani, Etna and Monti Sicani). As regards its ecological plasticity, it is present within Mediterranean-type plant consortia, either evergreen (such as scrubland formations and *Quercus ilex* L. and *Q. suber* L. forests) or deciduous (such as thermophilic deciduous oak forests). Due to its pronounced heliophilousness, the entity has also been found within the numerous degradation areas of the forest formations, such as fruticets, garigues, etc.; it also abounds within tree systems characterized by a reduced degree of cover (eucalyptus groves, pine forests, hazel groves, etc.).

Compared with the previous species, the surveys carried out on *Asparagus albus* revealed a lower ecological plasticity. On the edaphic level, a preference for poorly evolved substrates of chalky, calcareous and calcarenitic rocky nature was detected, without discarding, however, different environments such as clayey but still alkaline-reacting ones. The species also reveals limitations regarding the altitudinal range, pushing up to a maximum altitude of 600 m reached along the hottest slopes of the Madonie Mountains, between Scillato and Polizzi Generosa. From the bioclimatic point of view, the greater sensitivity to colder temperatures causes the species to extend from the dry infra-Mediterranean bioclimatic plane of the Pelagian Islands to the upper subhumid lower meso-Mediterranean (characterized by an average temperature between 13 and 16°C and a rainfall regime between 600 and 800 mm year^{-1}) of the inner Sicilian hills. Regarding its physiognomic role, *Asparagus albus* constitutes an exclusive element of degraded Mediterranean scrubland formations; it sometimes recurs within the warmest and sunniest holm oak forests.

Morphological and physiological characterization

All data were submitted to hierarchical cluster analysis, allowing the assessment of the degree of similarity/dissimilarity among the studied accessions, as well as clarifying some of the relationships between them (Mousavizadeh et al., 2015). The dendrogram clearly shows the partitioning between the two species, each being included in a separate cluster (Figure 3). This is certainly due to the large differences between the two species concerning morphological parameters, such as plant volume, and physiological traits, such as the flowering and fruiting percentages. It generally turns out that plants of *Asparagus acutifolius* have a smaller size and occupy a smaller volume than those of *A. albus*. In terms of physiological traits, the percentage of flowering and fruiting is significantly higher in *A.*

acutifolius, whereas the presence of spears is higher in *A. albus*.

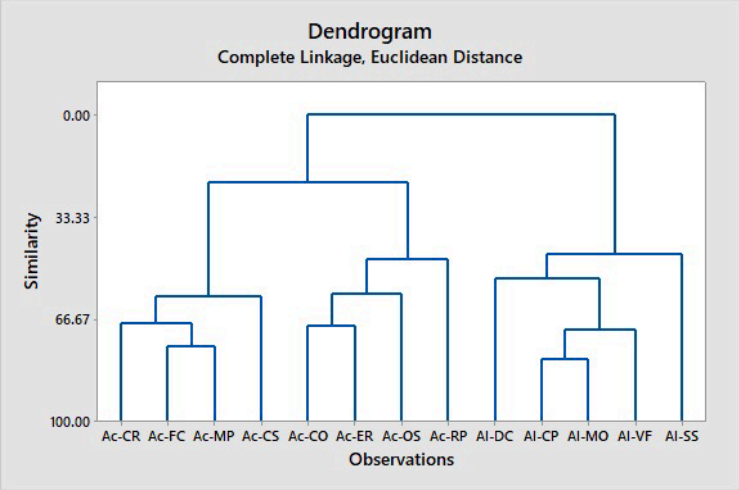

Figure 3. Cluster analysis dendrogram for 13 populations of *A. acutifolius* and *A. albus*.

The maximum estimated volume parameter, taken into account for the purpose of this study, was 22233.81 cm^3 in *Asparagus acutifolius*, and about half this value (11603.48 cm^3) in *A. albus*. The percentages of maximum flowering and fruiting for *A. acutifolius* were 75.52 and 29.51% respectively, and for *A. albus* 7.92 and 2.92%. In contrast, the maximum percentage of presence of shoots was 56.77% in *A. acutifolius*, while it reached a markedly higher value (91.67%) in *A. albus*.

At the following level, the dendrogram identifies a further separation within the populations of *A. acutifolius*. The diameter and height of plants, and hence their calculated volume, are the variables that are more responsible for this partitioning. The first group includes the populations Ac-CR, Ac-FC, Ac-MP and Ac-CS, reaching on average a smaller plant size (11019.09 cm^3) than the other populations (33448.53 cm^3 as the average group value for Ac-CO, Ac-ER, Ac-OS, and Ac-RP).

The greater growth ability of the populations belonging to the second group, compared to those in the first group, allowed us to conclude that the genotypes of the second group could be more suitable than the others for cultivation at the experimental site. Hence, for these genotypes, a specific experimental activity should be planned in the future.

CONCLUSIONS

The main achievements of this study were firstly the in-depth study of certain aspects of the ecology and distribution of *A. acutifolius* and *A. albus* in Sicily, which could form the basis for further studies, and secondly, a preliminary characterization and discrimination of the genotypes collected.

A considerable morphological and physiological diversity showed up between the two *Asparagus* species. The species showed marked differences in plant volume (as measured by the diameter and height of plants), but also in flowering and fruiting percentages, and presence of spears.

The cluster analysis mainly grouped the species according to their taxonomic classification and eventual potential use. As far as we know, no breeding programs have been performed for this vegetable in Sicily. The collected populations, however, have shown good potential and can be considered a starting point to encourage breeding designs. Future activities will involve agronomic trials for the evaluation of the variables that affect yield and spear characters, in order to effectively assess suitability for cultivation in semi-arid environments. The evaluation of disease resistance, the rejuvenation of the collected plant material and the enlargement of the collection will be further steps to take, with a view to germplasm and biodiversity preservation.

Literature cited

Arcidiacono, S., and Pavone, P. (1994). Erbe spontanee commestibili del territorio etneo. Bollettino Accademia Gioenia di Scienze Naturali *27*, 346–481.

Benincasa, P., Tei, F., and Rosati, A. (2007). Plant density and genotype effects on wild asparagus (*Asparagus acutifolius* L.) spear yield and quality. HortScience *42* (*5*), 1163–1166 https://doi.org/10.21273/HORTSCI.42.5.1163.

Boubetra, K., Amirouche, N., and Amirouche, R. (2017). Comparative morphological and cytogenetic study of five Asparagus (*Asparagaceae*) species from Algeria including the endemic *A. altissimus* Munby. Turk. J. Bot. *41* (*6*), 588–599 https://doi.org/10.3906/bot-1612-63.

Bozzini, A. (1959). Revisione cito-sistematica del genere *Asparagus* L. I: le specie di *Asparagus* della flora italiana e chiave analitica per la loro determinazione:(con Tavole XV–XVII). Caryologia *12* (*2*), 199–264 https://doi.org/10.1080/00087114.1959.10797078.

Della, A., Paraskeva-Hadjichambi, D., and Hadjichambis, A.Ch. (2006). An ethnobotanical survey of wild edible plants of Paphos and Larnaca countryside of Cyprus. J Ethnobiol Ethnomed *2* (*1*), 34 https://doi.org/10.1186/1746-4269-2-34. PubMed

Di Maro, A., Pacifico, S., Fiorentino, A., Galasso, S., Gallicchio, M., Guida, V., Severino, V., Monaco, P., and Parente, A. (2013). Raviscanina wild asparagus (*Asparagus acutifolius* L.): a nutritionally valuable crop with antioxidant and antiproliferative properties. Food Res. Int. *53* (*1*), 180–188 https://doi.org/10.1016/j.foodres.2013.04.026.

Ferrara, L., Dosi, R., Di Maro, A., Guida, V., Cefarelli, G., Pacifico, S., Mastellone, C., Fiorentino, A., Rosati, A., and Parente, A. (2011). Nutritional values, metabolic profile and radical scavenging capacities of wild asparagus (*A. acutifolius* L.). J. Food Compos. Anal. *24* (*3*), 326–333 https://doi.org/10.1016/j.jfca.2010.10.008.

García-Herrera, P., Sánchez-Mata, M.C., Cámara, M., Tardío, J., and Olmedilla-Alonso, B. (2013). Carotenoid content of wild edible young shoots traditionally consumed in Spain (*Asparagus acutifolius* L., *Humulus lupulus* L., *Bryonia dioica* Jacq. and *Tamus communis* L.). J Sci Food Agric *93* (*7*), 1692–1698 https://doi.org/10.1002/jsfa.5952. PubMed

Katsenios, N., Roussis, I.E., Efthimiadou, A., Kakabouki, I., and Bilalis, D. (2019). Seed treatment techniques to improve germination of wild asparagus (*Asparagus acutifolius* L.), a potential new crop. Not. Bot. Horti Agrobot. Cluj-Napoca *47* (*3*), 995–1000 https://doi.org/10.15835/nbha47311554.

Maccioni, S., Monti, G., Flamini, G., Cioni, P.L., Morelli, I., and Guazzi, E. (2004). Ricerche etnobotaniche in Liguria. La Val Lerrone e la Bassa Valle Arroscia. Atti della Società Toscana di Scienze Naturali. Memorie Serie B *11*, 129–134.

Martins, D., Barros, L., Carvalho, A.M., and Ferreira, I.C.F.R. (2011). Nutritional and in vitro antioxidant properties of edible wild greens in Iberian Peninsula traditional diet. Food Chem. *125* (*2*), 488–494 https://doi.org/10.1016/j.foodchem.2010.09.038.

Molina, M., Pardo-de-Santayana, M., García, E., Aceituno-Mata, L., Morales, R., and Tardío, J. (2012). Exploring the potential of wild food resources in the Mediterranean region: natural yield and gathering pressure of the wild asparagus (*Asparagus acutifolius* L.). Span. J. Agric. Res. *10* (*4*), 1090–1100 https://doi.org/10.5424/sjar/2012104-3050.

Mousavizadeh, S.J., Hassandokht, M.R., and Kashi, A. (2015). Multivariate analysis of edible *Asparagus* species in Iran by morphological characters. Euphytica *206* (*2*), 445–457 https://doi.org/10.1007/s10681-015-1508-y.

Pieroni, A., Nebel, S., Santoro, R.F., and Heinrich, M. (2005). Food for two seasons: culinary uses of non-cultivated local vegetables and mushrooms in a south Italian village. Int J Food Sci Nutr *56* (*4*), 245–272 https://doi.org/10.1080/09637480500146564. PubMed

Rosati, A. (2001). Un possibile futuro per l'asparago. Inf. Agrar. *7*, 89–92.

Rosati, A., and Falavigna, A. (2000). Germinazione dei semi di asparago selvatico. Inf. Agrar. *56*, 53–55.

Rosati, A., Castellini, C., Dal Bosco, A., Mugnai, C., and Paoletti, A. (2012). Manuale per la Coltivazione Consociata: Olivo, Asparago Selvatico, Pollo Rustico. Edizioni 3A-PTA.

Sánchez-Mata, M., Matallana-González, M., and Morales, P. (2016). The contribution of wild plants to dietary intakes of micronutrients (I): vitamins. In Mediterranean Wild Edible Plants, M. Sánchez-Mata, and J. Tardío, eds. (New York: Springer), p.111–139 https://doi.org/10.1007/978-1-4939-3329-7_6.

Sautour, M., Miyamoto, T., and Lacaille-Dubois, M.A. (2007). Steroidal saponins from *Asparagus acutifolius.* Phytochemistry *68* (*20*), 2554–2562 https://doi.org/10.1016/j.phytochem.2007.02.033. PubMed

Tirado, R., and Pugnaire, F.I. (2003). Shrub spatial aggregation and consequences for reproductive success. Oecologia *136* (*2*), 296–301 https://doi.org/10.1007/s00442-003-1264-x.

United States Science and Education Administration. (1975). Soil Taxonomy: a Basic System of Soil Classification for Making and Interpreting Soil Surveys. No. 436 (US Department of Agriculture), https://www.nrcs.usda.gov

Venezia, A., Soressi, G.P., and Falavigna, A. (1993). Aspetti relativi alla valorizzazione di specie di asparago spontanee in Italia. Agricoltura e Ricerca *141*, 41–48.