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Exploring the potential of wild food resources in the Mediterranean region: natural yield and gathering pressure of the wild asparagus (*Asparagus acutifolius* L.)

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Abstract

In the Mediterranean region, some wild edible species such as *Asparagus acutifolius* L. are still harvested and even marketed. Considering the great interest of this species, including its recreational, commercial and agronomic uses, we aimed to study its natural supply and its current scale of harvesting. Nearly 50 plants were monitored in two sites of Central Spain. An experimental harvest of 100% of spears was conducted during spring 2008-2009 to estimate spear production per plant and per hectare. Plants were also monitored but not harvested in 2010-2011 at Site 1 to document real gathering practices and its influence on yield. Spear production ranged from 5.0 to 12.8 g per plant and from 4.0 to 8.9 kg ha^{-1}, reaching the top-ranked values in May (30-60% of total yield). Between-site variations on yield were mainly related to spear number rather than to spear weight, whereas weather conditions influenced annual yields. The percentage of plants harvested by local foragers varied from 26 to 47%. A slight but not significant trend for collecting the largest spears was recorded. According to spear number in harvested (1.8-2.5 spears) and non-harvested plants (1.3-1.5 spears), gathering seemed to promote the growth of new spears, although further research is needed to assess its influence in the long term. Results suggest that foraging is a time-consuming practice, thus social and cultural factors may explain its high appreciation in present times.

Additional key words: applied ethnobotany; gathering; non timber forest products; spear yield; wild edible plants.

Resumen

Potencial de las plantas silvestres comestibles en la región mediterránea: producción y presión recolectora del espárrago triguero (*Asparagus acutifolius* L.)

En la región mediterránea, especies como el espárrago triguero (*Asparagus acutifolius* L.) siguen siendo recolectadas y a veces incluso vendidas en mercados locales. Dado el interés de esta especie, tanto recreativo como agronómico o comercial, en este trabajo se estima su producción natural y su presión recolectora en la actualidad. Para ello se realizó el seguimiento de casi 50 esparragueras silvestres en dos localidades del centro de España. En la primavera de 2008 y 2009 se recolectaron el 100% de los espárragos para estimar el número y peso de espárragos por planta y por hectárea. La presión recolectora se ha estudiado durante los años 2010-2011 en las mismas plantas de una de las dos poblaciones. La producción estimada fue de 5,0-12,8 g por planta y 4,0-8,9 kg ha^{-1}, alcanzando los valores más altos en mayo (30-60% del rendimiento total). Entre localidades aparecieron mayores diferencias en el número de espárragos que en el peso de los mismos. Las condiciones meteorológicas influyeron en los rendimientos anuales. Se observó que el 26-47% de las esparragueras fueron cosechadas por recolectores locales. Se detectó una ligera pero no significativa tendencia a recolectar los espárragos de mayor tamaño. Basándonos en el número de espárragos de las plantas recolectadas (1,8-2,5 espárragos) y no recolectadas (1,3-1,5 espárragos), parece que la recolección promueve el crecimiento de nuevos espárragos, aunque se precisa corroborarlo con una investigación a más largo plazo. Los resultados

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sugieren que la recolección de espárragos es una práctica que consume mucho tiempo, por lo que seguramente existen otros factores sociales y culturales que explican el aprecio que se les tiene en la actualidad.

Palabras clave adicionales: producción de espárragos; recolección; plantas silvestres comestibles; productos forestales no maderables; etnobotánica aplicada.

Introduction

World-wide attention is given to the broad range of products and services derived from forests (Janse & Ottitsch, 2005; Emery *et al.*, 2006). The harvest of non-timber forest products (NTFPs) represents a relevant source of incomes in cash or in kind to millions of people in the world, which are still highly dependent on them (Ticktin, 2004; Dovie *et al.*, 2007). In the Mediterranean region, some recreational and commercial uses of NTFPs, such as hunting and game or mushrooms picking, are even becoming more important (Croitoru, 2007; Martínez-Jauregui *et al.*, 2011).

Although wild food harvesting is no longer a subsistence practice in developed countries, it is considered a leisure activity that seems to be increasing in the last years (Colombo *et al.*, 2010). Indeed, recent studies concluded that gathering is practiced for a substantial subset of the general population, coming from different socio-economic backgrounds (Robbins *et al.*, 2008), and providing a wide array of benefits, such as (i) access to material products, (ii) enhanced social interaction, (iii) maintenance of cultural traditions, and (iv) physical, emotional and spiritual well-being (Emery *et al.*, 2006; McLain *et al.*, 2012). Coupled with such benefits, nutritional and epidemiological studies have showed that diets rich in wild-growing foods may be far healthier than those dominated by processed foods (Trichopoulou & Vasilopoulou, 2000; Cordain *et al.*, 2005; Sánchez-Mata *et al.*, 2012).

The abundance and yield of these wild food resources have not been properly studied, with the exception of some wild berries (Kerns *et al.*, 2004; Murray *et al.*, 2005; Miina *et al.*, 2009; Molina *et al.*, 2011) and mushrooms (Martínez de Aragón *et al.*, 2007; Bonet *et al.*, 2008). However, there is a large set of wild-growing species used in traditional cuisines that deserve more attention (Pieroni *et al.*, 2005; Tardío *et al.*, 2006). These plants usually escape from formal markets or are only collected for domestic consumption. For that reason, it is difficult to assess the current scale of gathering, the number of collectors involved, and its economic importance (Sanderson & Prendergast, 2002). Further research is needed to gain a broader picture of the production and management of these plants; taking into account other minor but culturally important species used in traditional food systems, such as the wild asparagus.

Although other wild species, such as *Asparagus albus* L. and *Asparagus aphyllus* L., are also used, *Asparagus acutifolius* L. (Asparagaceae) is the more widely distributed in the Mediterranean basin, mainly growing in woodlands and shrublands (Tutin *et al.*, 1980). It has been gathered since ancient times (Font Quer, 1961) and it is highly appreciated in Spain (Tardío *et al.*, 2006), Portugal (Mendonça de Carvalho, 2006), southern France (Chauvet, 2001), Italy (Ghirardini *et al.*, 2007), Turkey (Ertug, 2004) and Cyprus (Hadjichambis *et al.*, 2008). This plant can also be found in agricultural landscapes, especially in olive groves (Benítez, 2009) and formerly in cereal crops (Tardío, 2010), as indicated by its Spanish popular name *espárrago triguero* ('asparagus from the wheat fields'). The wild asparagus is considered a healthy food used in folk medicine as diuretic to treat several kidney related disorders (Signorini *et al.*, 2009; Vallejo *et al.*, 2009; Benítez *et al.*, 2010). It is consumed cooked in different dishes, although it is preferred with eggs, *i.e.* omelettes, scrambled or poached eggs (Pieroni *et al.*, 2005; González *et al.*, 2010). According to nutritional studies, the spears of *A. acutifolius* are rich in flavonoids and vitamin C, showing a high antioxidant activity even when examined after boiling (Fuentes-Alventosa *et al.*, 2007; Martins *et al.*, 2010; Morales *et al.*, 2011). Specifically, their content of ascorbic acid is more than fivefold higher than that from the cultivated asparagus, *A. officinalis* L. (Ferrara *et al.*, 2011).

In some Spanish areas, traditional harvesting is carried out mainly by men (Catani *et al.*, 2001), as other plants that grow far away from the villages (Nebel *et al.*, 2006). Besides household consumption, bunches of asparagus are sold in local markets to complement rural income (Chauvet, 2001; Mendonça de Carvalho, 2006; Tardío, 2010). They are highly valued and reach high market prices (Rosati *et al.*, 2005). A harvester selling bunches of wild asparagus of about 250 g at €5 was found by the authors in the province of Madrid in 2012. New foraging trends have currently been ob-

served. Recreational harvesting of *A. acutifolius* attains new collectors such as retired people and Sunday excursionists from urban areas (Catani *et al.*, 2001), and a renewed interest for commercial harvesting is arising. In some regions, the presence of wild asparagus in local markets and restaurants is comparable to those reported for some mushrooms (Parada *et al.*, 2011). They are also offered as a special gift among relatives or neighbours, being considered as a valuable good in the 'moral economy' of the villages, ruled by the moral values attached to the product and the donor ability to collect it (Acosta & Díaz, 2008).

For a few years now, attempts have been made to domesticate this species with the aim of increasing its productivity and ensuring an efficient supply for developing a stable market (Rosati, 2001; Benincasa *et al.*, 2007). It is considered an interesting crop for marginal rural areas due to its frugality, which allows it to be cultivated in arid soils, and for its already existing market (Aliotta *et al.*, 2004). Given the great interest that is currently being shown in the wild asparagus (recreational, commercial, and agronomic), this research aims to contribute to the valorisation and sustainable use of *A. acutifolius* by providing original data in two topics that have been scarcely addressed: (i) the natural yields of the wild asparagus and (ii) its current scale of gathering. The study was designed from an ecological approach in order to complement the ethnobotanical information of this species and draw temporal patterns of spear yield and gathering during the harvest season.

Material and methods

Field work was conducted during 2008-2011 in two locations of the province of Madrid (Central Spain): Monte de Valdelatas (Site 1) and Soto del Henares (Site 2) where we had previously observed people collecting *A. acutifolius*. Two different procedures were used. Firstly, during 2008-2009, the asparagus yield per plant was estimated by harvesting and weighing the 100% of spears of 50 selected plants in both sites, and assessing the site and weather effects on yield. As gatherers could harvest the marked plants, they were periodically monitored and missing spears were identified by the lignified basal part of the stem that remains above ground when the tender upper part is picked up. We combined yield data with plant density values to ascertain the approximate production per hectare. Secondly, due to the proximity to the city of Madrid and its free access, the population of Site 1 was selected to evaluate the current scale of gathering during 2010-2011. The number and diameter of spears collected by local foragers were recorded in order to document the harvesting practices observed in this period and its influence on yield.

Study sites

Site 1 (40°32'N; 03°41'W, 690 m altitude) is located in the north of Madrid city, near the Universidad Autónoma de Madrid (Fig. 1). A holm oak (*Quercus ilex* L.) forest occurs along most of the territory, except for some areas reforested with *Pinus pinea* L. Field work was conducted in a 30 ha plot located in the holm oak forest, where *A. acutifolius* is a frequent understory species. Its sandy soil was originated on sediments derived from granite. Riparian species such as *Salix atrocinerea* Brot., *S. salviifolia* Brot., *Populus nigra* L. and *P. alba* L., and thorny vegetation, such as *Rubus ulmifolius* Schott, *Crataegus monogyna* Jacq. and *Rosa* spp., can be found in the valleys, on alluvial and slightly clayey soils. Its climate is Mesomediterranean with a total annual rainfall of 459 mm and annual average temperature of 13.7°C (SIGA, 2011). Since the study area is 15 km away from the centre of the city of Madrid and 6 km from the nearby city of Alcobendas, it is widely visited, especially at the weekends.

Site 2 (40°31'N; 03°17'W, 600 m altitude) is located in the east of the province of Madrid into the fertile plain of the Henares River (Fig. 1). The rich lowlands have been traditionally used for agricultural production and, lately, for industrial uses in some areas. Despite anthropic pressures, however, the landscape preserves one of the best river bank forests of this province (Martínez, 2000). The study area comprises two different sections; one of them is located in the riverside of the Henares River and the other one in a nearby small stream. Tree species composition mainly includes *P. alba*, *Salix alba* L. and *Tamarix gallica* L. in the first section while it is dominated by *P. alba* and *Ulmus minor* Mill. in the second one. The population of *A. acutifolius* occurs within the first 10 to 15 m from the shoreline. Two plots of 2 ha and 4 ha corresponding respectively with 0.4 and 0.6 km of the riversides were delimited for the study. Woodlands grow in limestone and sandy soils with clay. Total annual rainfall is 433 mm and annual average temperature 13.5°C (SIGA, 2011). Site 2 is also close to urban areas

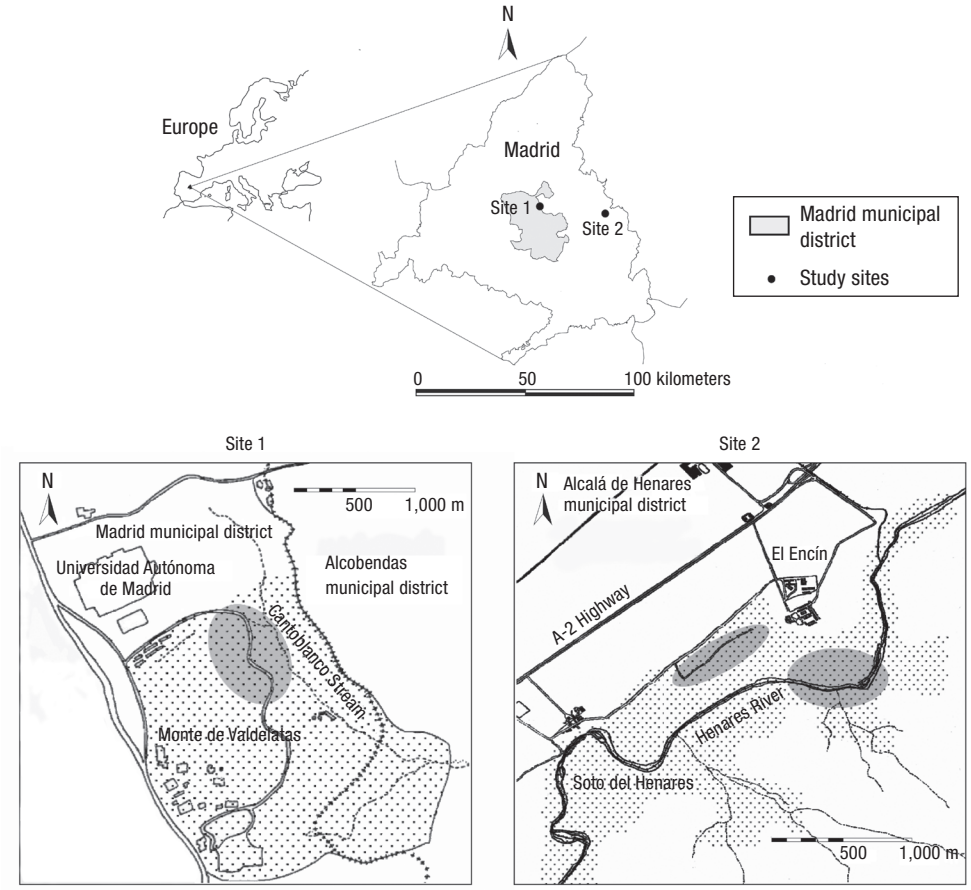

Figure 1. Study sites: Monte de Valdelatas (Site 1) and Soto del Henares (Site 2). Based on Génova (1989) and Comunidad de Madrid (2000).

(38 km away from the city of Madrid and 4 km from the nearby city of Alcalá de Henares), although the access by car is restricted.

Plant monitoring

Since several spears can be collected in the same specimen, 50 randomly selected plants per site were thoroughly monitored along the gathering periods. These plants were marked with a tag and mapped with a GPS receiver. Plant size of the selected specimens was estimated the first year of the study, in 2008, by plant stem diameter at the base of the thickest mature stem. Missing plants which could not be checked all over the years of study were eliminated. Therefore, as shown in Table 1, asparagus yield was successfully monitored in 47 and 41 plants at Site 1 and Site 2 respectively.

Plants were sampled at 8-12 days intervals during the gathering period, when the spears began to grow reaching the surface, visiting them until new spears were not found. Overall, we conducted 7-10 sampling visits per year at the surveyed areas. The length of the harvesting period depended on the annual meteorological conditions and, as can be seen in Table 1, started at the end of March or the beginning of April, and finished at the end of May and exceptionally at June or July. It was exceptionally longer in 2008 (almost 90 days long) at both locations and much shorter in 2009 (almost 60 days long), whereas it approximately lasted two months and a half in 2010 and 2011 at Site 1.

Asparagus yield estimates

According to our first goal, the production of *A. acutifolius* was estimated over a 2-years period (2008-2009) at Site 1 and Site 2. The spears of the marked plants were periodically collected and separately weighed. They were picked by hand at the height they snapped easily when

Table 1. Harvesting period and general results of the samplings at the two sites surveyed

	Site 1				Site 2	
	2008	**2009**	**2010**	**2011**	**2008**	**2009**
Monitored plants	47	47	47	47	41	41
First/last date of harvesting (dd-mm)	11-04/7-07	3-04/31-05	23-04/9-07	8-04/20-06	27-03/19-06	27-03/25-05
Harvesting period (days)	87	58	77	73	84	59
Sampling visits	9	8	9	9	10	7
Plants with null yield	6	5	3	9	1	6
Plant stem diameter (mm)[a, b]	5.6 ± 0.1A	–	–	–	6.1 ± 0.3A	–
Plant density (individuals ha^{-1})[a]	1,728 ± 232A	–	–	–	374 ± 182B	–

[a] Capital letters mean significant differences between sites ($p \leq 0.05$). [b] Diameter of the thickest mature stem.

they were bent, thus spear length was variable, approximately from 8 to 30 cm. The yield variables estimated were: (i) number of spears per plant, (ii) individual spear weight (g) and (iii) total spear weight per plant (g), *i.e.* cumulative yield from the beginning to the end of the gathering period. Spear yield was expressed as fresh weight. As mentioned before, those spears occasionally picked by other collectors were also registered to avoid biased estimates in spear number. In these cases, missing values in individual spear weight were replaced by the average value.

The production per hectare was indirectly calculated based on asparagus yield per plant and plant density. For that purpose, the number of individuals growing in at least 30 randomly located transects of 25 × 3 m was counted within the study areas. Sampling was conducted in 2008, assuming that the number of plants occurred in both sites would remain stable over the study years in this perennial species. The mature stems and the new spears of *A. acutifolius* growing less than 20 cm apart and apparently originating from the same rhizome were considered a single specimen. This criterion was followed to assess individual plant yield and plant density in controversial specimens growing close together.

Asparagus yield per plant was also analysed by two weeks periods in order to study the temporal patterns of yield and weather influence. Mean temperature and total rainfall of the harvesting period were considered. Meteorological data were taken from the nearest stations to Site 1 and 2 (El Goloso and El Encín respectively).

Harvesting practices

The same plants monitored in 2008-2009 at Site 1 were periodically checked during the gathering periods of 2010 and 2011. However, in this occasion, to assess the current scale of gathering, we did not collect any spears, counting only the observed number of picked and non-picked spears. Picked spears were detected by the basal part of the cut stems. We estimated (i) the number of spears per plant, and (ii) spear diameter at the base. Since spear weight was not measured in this period, the size of the spears was evaluated by their diameter. Yield variables were separately calculated for harvested and non-harvested plants in order to document the harvesting practices conducted by local pickers and its influence on yield.

Statistics

Mean ± standard error (SE) were calculated for all the variables. Normality assumptions required for ANOVA were not reached in all of them ($p < 0.05$; Kolmogorov test). Therefore, the non-parametric Mann Whitney U test was used to test whether there were significant differences between both sites and harvesting practices for the yield variables evaluated in each year. Between-year differences were assessed by Wilcoxon test for repeated-measures in the same plants. Correlation analyses were also performed to study the influence of plant size on yield. All the procedures were tested with $\alpha = 0.05$.

Results and discussion

As shown in Table 1, 81-98% of the 47 and 41 plants surveyed at Site 1 and Site 2 respectively produced spears during all the years of the study. A small number of plants did not yield any spears despite they had photosynthetic-active stalks. According to plant stem diameter at the base of the thickest mature stem, asparagus plants at both sites were not statistically

different in size, although the plants at Site 2 had slightly thicker stems (6.1 ± 0.3 mm) than those at Site 1 (5.6 ± 0.1 mm). On the contrary, the Site 1 population was found to be considerably higher in terms of plant density (1728 ± 232 plants ha^{-1}) than the Site 2 population (374 ± 182 plants ha^{-1}).

Asparagus yield

Spear number and weight

The production of wild asparagus at the two surveyed sites is shown in Table 2. As it can be observed, a lower number of spears was recorded in 2009 at both locations, as could be expected because of the shorter gathering period. Significant differences between sites for both spears per plant and yields per plant were obtained with Site 2 population showing the highest values, whereas non-significant differences were recorded in spear weight. Results agree with previous studies wherein variations on spear yield were mainly related to spear number instead of spear weight. As stated by Benincasa *et al.* (2007), this might result from the limited ability of *A. acutifolius*, unlike *A. officinalis*, to increase spear diameter in response to abundant reserves. Therefore, increasing spear emergence remains the only outlet for the plant to spend reserves. In our study, the favourable ecological characteristics of the river bank forest sampled at Site 2, such as soil humidity and fertility, may explain the higher spear number and yield recorded at this location. However, even though the lower production per plant of Site 1, this population showed much higher plant density values and consequently the highest yield rates per hectare.

Our yield estimates for the two wild populations of *A. acutifolius* were obviously lower than those reported in *A. officinalis*. Cultivated asparagus are significantly larger, with a much higher individual spear weight ranging from 10 to 125 g (Maroto, 1986), and crop yields are consequently more than double of those found in our wild species. Likewise, the annual yields recorded for wild *A. acutifolius* were also lower than those described for the same species in cultivation experiments. Previous studies conducted in Italy by Rosati *et al.* (2005) and Benincasa *et al.* (2007) reported crop yields of 20-45 g per plant. The better growing conditions of the plants under culture (cultivated soil, fertilization, irrigation and weed control) were surely responsible of these considerable differences. Besides, it should be taken into account that our estimations of spear weight could be slightly underestimated by two reasons. Firstly, we harvested some small spears that maybe would have reached a larger size if collection had delayed a few days, and secondly, we only weighed the edible part of the asparagus, whereas Benincasa *et al.* (2007) weighed longer asparagus with only a 37% of edible part and therefore the final figures might have been much more similar (about an average of 7.5 g $spear^{-1}$).

The spear production of *A. acutifolius* could also be influenced by other factors previously recorded to be important in *A. officinalis*, such as plant age and sex. Crop yields described for *A. officinalis* range from 2-4 tons ha^{-1} in the fourth year to 6-8 tons ha^{-1} during the sixth to tenth year after planting (Maroto, 1986). In addition, male plants are more productive and have greater longevity than female ones, though the spears tend to be thinner than those of female plants (Aliotta *et al.*, 2004). It might influence spear yields in other dioecious species such as *A. acutifolius* and could be assessed in further researches.

Yield patterns and weather influence

The fortnightly values of yield per plant, expressed as the percentage of total yield obtained in each

Table 2. Yield variables measured for *Asparagus acutifolius* at two sites (mean ± SE)

	Site 1			Site 2		
	2008	**2009**	**Total**	**2008**	**2009**	**Total**
Spears per plant	2.2 ± 0.2aA	1.6 ± 0.2bA	1.9 ± 0.1A	4.4 ± 0.7aB	4.1 ± 0.7aB	4.2 ± 0.5B
Spear weight (g)	2.3 ± 0.1aA	3.3 ± 0.3bA	2.7 ± 0.2A	2.4 ± 0.1aA	3.2 ± 0.2bA	2.8 ± 0.1A
Yield per plant (g)	5.0 ± 0.6aA	5.2 ± 0.8aA	5.1 ± 0.5A	10.6 ± 1.7aB	12.8 ± 2.3aB	11.7 ± 1.4B
Yield per hectare (kg ha^{-1})	8.6 ± 1.2aA	8.9 ± 1.2aA	8.8 ± 0.8A	4.0 ± 1.9aB	4.9 ± 2.4aB	4.4 ± 1.5B

In each row, different small letters indicate statistical differences between years in the same location according to Wilcoxon test and capital letters denote significant differences between sites by Mann Whitney U test ($p \leq 0.05$).

period, are represented in Fig. 2. As it can be observed, the top-ranked values of spear production were mainly reached in May, except for a prominent rise of production observed in the first half of June 2008 at Site 1.

The seasonal patterns of rainfall and mean temperature are shown below in Fig. 2. According to meteorological data, spring 2008 was rainier and temperature surpassed 20°C in the second half of June, whilst in 2009 temperature increased over 20°C in May. Spear emergence was presumably prolonged in 2008 because of these favourable weather conditions. However, total spear yield at the end of the harvesting periods 2008 and 2009 did not differ significantly (see Table 2).

Despite the combination of hot temperatures and rainfall shortage in spring 2009, spear production by two-week periods was surprisingly higher in this year. Trying to explain such results, weather conditions previous to the gathering period were considered. As reported in *A. officinalis*, the storage compounds synthesized during the growing season and accumulated in the rhizome have shown to play an important role in the yield of the next year (Maroto, 1986). Similar patterns could be expected in *A. acutifolius* since it is also a perennial plant with underground storage organs. Accumulated rainfall from March of the previous year until the month before gathering was higher in 2009 (620 mm at Site 1 and 512 mm at Site 2) than in 2008 (458 mm and 405 mm respectively), revealing better weather conditions for plant growth. Our results suggest that the storage energy can be decisive at the beginning of the growing season until the photosynthetic-active stalks could recharge the root reserves and promote the growth of new spears. However, long-term studies are needed to confirm the results of our 2-years analysis.

Yield estimations and gathering effort

The low production rates herein described in *A. acutifolius* growing wild suggest that too much time is spent on gathering. Taking into account the total yield per plant and the number of visits conducted (see Tables 1 and 2), the average number of spears collected per plant in a journey was 0.22 and 0.51 spears

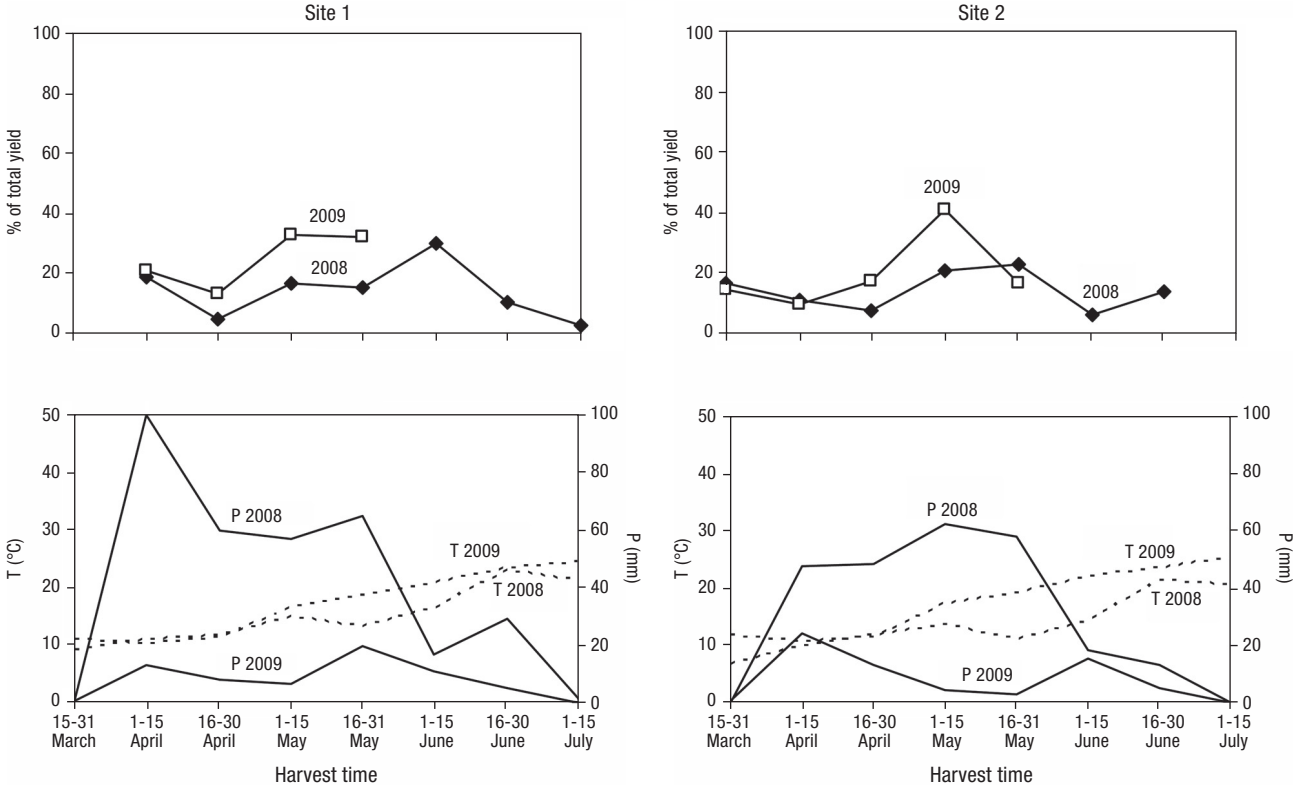

Figure 2. Average yield per plant, expressed as the percentage of total yield obtained in each period, and seasonal patterns of precipitation (P) and temperature (T) during harvest time.

at Site 1 and 2 respectively. If the corrected mean weight of the spears is also considered (7.5 g spear^{-1}), around 65 (Site 2) or 150 (Site 1) plants should be visited to obtain a 250 g bunch of wild asparagus.

In order to study the influence of plant size (estimated as plant stem diameter) on yield, and its potential implications on the gathering process, a correlation analysis was performed with spear weight and number of spears per plant. Plant stem diameter was only significantly correlated with spear weight ($r = 0.63$, plants from both sites combined), revealing that the plants with higher stem diameter tended to produce larger spears as well, while they did not necessarily have a lower production in terms of number of spears. According to such results, the knowledge of the location of the largest specimens could optimize the too time-consuming practice of foraging. It would explain why pickers are so highly secretive about the locations of the finest specimens, in a similar manner to wild mushrooms gatherers (González, 2002).

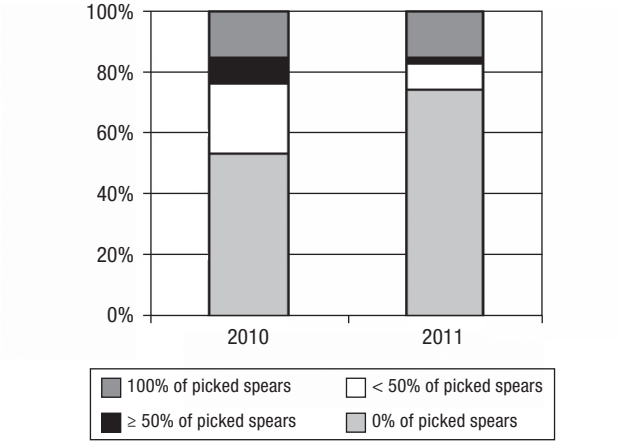

Figure 3. Percentage of harvested and non-harvested plants ($n = 47$ plants) according to the harvesting practices observed at Site 1 in 2010 and 2011 (0%, < 50%, ≥ 50% and 100% of picked spears from total spears yielded per plant).

Harvesting practices

Current scale of gathering

According to our second goal, the current scale of gathering was evaluated at Site 1 during 2010-2011 in the same 47 monitored plants. Overall, harvesting was found to be important in 2010, with 47% of the sampled plants harvested by local foragers (22 plants), and much lesser in 2011, with only 26% of harvested plants (12 plants). As shown in Fig. 3, the percentage of spears picked up in these plants was variable, with an average value of 66% and 81% of picked up spears in 2010 and 2011 respectively. Only 15% of the monitored plants (7 plants) were fully harvested in both years (100% of spears picked).

It should be considered that individual collection rates may differ considerably depending on the specific location of plants. Since spears are not easy to find, even for trained eyes, harvesting pressure could increase in those plants growing in open habitats. Indeed, we observed that other asparagus plants growing in a pine grove located nearby the study area were completely harvested. In our study, however, the plants growing in the holm oak forest at Site 1 were randomly selected, thus some of them grew in inaccessible habitats surrounded by thorny vegetation whereas others were located nearby pathways, making spear collection easier. Harvesting impacts could also vary depending on harvesting practices. The spears of *A. acutifolius* are traditionally cut above ground level, when they are tall and lignified at the base (Ferrara *et al.*, 2011). In this way, plants continue growing through the lateral buds which remain in the lower part of the stem. This sustainable practice would let the plant finish the reproductive cycle successfully, as well as synthesizing storage compounds to begin the next season's growth. In some places, gatherers cut the plants with a sickle for promoting the appearance of more spears and to difficult the location of the plants to other gatherers. However, this practice may difficult the survival of the plant and the accumulation of reserves, since the photosynthetic part of the plant is eliminated.

Spear number and diameter

Significant differences were recorded between harvested (1.8-2.5 spears on average) and non-harvested plants (1.3-1.5 spears) for spears per plant in both years (Table 3). According to present data, the gathering seemed to promote the growth of new spears during the harvesting season. However, it could also be that gatherers preferably collected those plants with more spears, as they are more visible. Additionally, the plants monitored at this location in 2008-2009 yielded a similar number of spears than in 2010-2011, suggesting that the experimental harvest of 100% of spears in 2008-2009 did not compromise spear yield in the fol-

Table 3. Yield variables measured in harvested (H) and non-harvested (NH) plants (mean ± SE) on wild *Asparagus acutifolius* at Site 1 in 2010-2011

	2010			2011		
	H	**NH**	**Total**	**H**	**NH**	**Total**
Spears per plant	2.5 ± 0.3aA	1.5 ± 0.2bA	2.0 ± 0.2A	1.8 ± 0.2aA	1.3 ± 0.2bA	1.4 ± 0.2B
Spear diameter (mm)	4.9 ± 0.2aA	4.4 ± 0.2aA	4.7 ± 0.1A	4.4 ± 0.2aA	4.5 ± 0.2aA	4.5 ± 0.1A

In each row, different lower case letters indicate statistical differences between harvested and non-harvested plants in the same year (Mann Whitney U test, $p \leq 0.05$) and different capital letters denote significant differences between years (Wilcoxon test, $p \leq 0.05$).

lowing years. Further studies are needed to assess the potential implications of harvesting for the reproduction of this species in the long term. As described in other NTFPs, environmental variation could mask the effects of harvest or it could exacerbate harvesting impacts, thus it may be difficult to determine conclusively whether there is an effect of harvest on plant growth (Schmidt *et al.*, 2011). Regarding spear diameter no significant differences were recorded between harvested and non-harvested plants in both years (Table 3). A slight but not significant trend for collecting the largest spears was observed in 2010. However, a larger data set would be necessary to determine conclusively if harvesting practices vary according to spear diameter.

Patterns of gathering

The number of spears collected in each period, expressed as the percentage of total spears gathered, is shown in Fig. 4. Gathering was mainly conducted in April and the beginning of May (87% and 81% of total gathering in 2010 and 2011 respectively), suggesting that asparagus from early spring are preferred by foragers. It agrees with the traditional saying 'those from April for me, those from May for my brother, and those from June for nobody' (Tardío *et al.*, 2002). On the contrary, most spears from late spring remained unharvested since gathering did not generally extend beyond May. The spears picked up from the end of May to June only comprised the 13% and 19% of total gathering, presumably because they are more fibrous and its visibility is lower when the understory vegetation becomes impassable.

This paper offers quantitative data on yield and gathering rates of the wild asparagus that may contribute to the valorisation and sustainable use of this species. According to our results, gathering *A. acutifolius* is still a common practice that seems to be mainly linked to social and cultural factors rather than the trade-off between kilogram of spears harvested and harvesting effort. It explains why foragers usually visit repeatedly the same harvesting places, where they already know the location of the largest specimens, in order to optimize the gathering process.

Given the great cultural interest of this species, harvesting wild asparagus from the wild could be complemented by spear collection in olive (*Olea europaea* L.) groves, where asparagus plants occur spontaneously, to avoid overharvest in other wild populations. It could be a complementary economic resource since they have similar ecological requirements and *A. acutifolius* grows under both sun and shade expositions (Rosati, 2001). Additionally, spears could be harvested directly by the consumers in pick-your-own operations associated with tourism (Benincasa *et al.,* 2007). Integrating NTFPs into field crop cultivation is an interesting alternative, since it eases pressure on forests and help control soil erosion on agricultural lands (Pandit & Kumar, 2010).

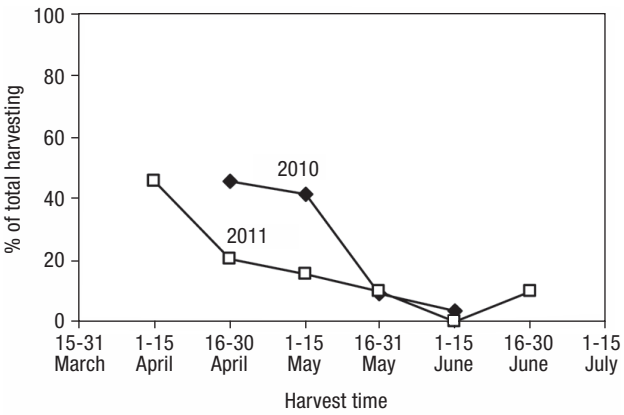

Figure 4. Average number of picked up spears per plant at Site 1, expressed as the percentage of total spears gathered in each period.

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