Weeds and Food Diversity: Natural Yield Assessment and Future Alternatives for Traditionally Consumed Wild Vegetables

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WEEDS AND FOOD DIVERSITY: NATURAL YIELD ASSESSMENT AND FUTURE ALTERNATIVES FOR TRADITIONALLY CONSUMED WILD VEGETABLES

María Molina,1 Javier Tardío,2 Laura Aceituno-Mata,3 Ramón Morales,4 Victoria Reyes-García,5 and Manuel Pardo-de-Santayana6

Wild edible plants, and particularly weeds, continue to be an important dietary component of many people around the world. We study the availability and yield of 15 weedy vegetables traditionally consumed in the Mediterranean region to assess their potential sustainable exploitation. Fieldwork was conducted in Central Spain during 2007–2009. Yields ranged between 10–460 g per plant in non-clonal species and between 400–5,000 g m\(^{-2}\) in clonal species. According to local plant density estimates, a total of 1800 kg ha\(^{-1}\) for Foeniculum vulgare, 700–1000 kg ha\(^{-1}\) for Beta maritima, Rumex pulcher, Papaver rhoeas and Silybum marianum, and 80–400 kg ha\(^{-1}\) for the remaining species could be obtained, except for Scolymus hispanicus that only yielded 30 kg ha\(^{-1}\). Exploitation of those species should consider local yields and preferences to achieve sustainability. We propose: 1) organic cultivation for highly valued species with low production rates in the wild (e.g., Scolymus hispanicus and Silene vulgaris); 2) commercial wild collection for culturally appreciated species with high yields in the wild (e.g., Allium ampeloprasum and Chondrilla juncea); and 3) maintenance of traditional practices and rates of harvest for all species for self-consumption.

Keywords: Mediterranean wild edible plants, food production, harvesting, organic farming, applied ethnobotany

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Introduction

Food diversity includes domesticated plant and animal species, but also wild animal and plant species. Given the profound changes in agricultural practices and in culinary and nutritional habits, food diversity is globally decreasing. Globalization and modernization have resulted in diet simplification and an increased dependency on a few staple crops for most nutritional needs (Johns and Eyzaguirre 2006). Food homogenization relates not only to the consumption of fewer species, but also to intra-species homogenization. According to FAO (2004), about 75% of the genetic diversity of agricultural crops was lost during the last century. Many local varieties of crops and animal breeds are threatened by extinction and most wild edible plants are not consumed anymore or only seldom (Flyman and Afolayan 2006; Ford-Lloyd et al. 2011).

The decrease of food diversity has led to an increasing concern among researchers, consumers, and farmers about its effects in human health, food security, and food sovereignty (Ayres and Bosia 2011; Dowler and O’Connor 2012; Johns and Eyzaguirre 2006). Both scientists and social movements are aware of the need for policies that promote diversified and environmentally and socially sustainable food production systems (Altieri et al. 2012; La Via Campesina 2012; Slow Food 2012).

In the context of this work, we define wild edible plants as plant species used as sources of food that are neither cultivated nor domesticated but available from their wild natural habitats, including weeds growing in agricultural and disturbed areas. Traditional food systems have typically used a large number of wild edible plants, including weedy relatives of crops. Weeds probably began to contribute substantially to the human diet with the beginning of agriculture, which favored the development of their ecological niches. They were a back-up resource in times of shortage, accounting for a significant input of micronutrients and allelochemicals with a prophylactic effect (Leonti 2012). Nowadays, the consumption of wild edible plants, although often difficult to assess, is still significant at local and global scales (Bharucha and Pretty 2010; Legwaila et al. 2011). Particularly, ethnobotanical surveys in the Mediterranean region reflect that gathering wild edible plants is at the crossroad of two divergent tendencies: 1) a decline in the habit of eating wild edible plants among the general population; and 2) a renewed interest among some young and middle-aged urban classes interested in the consumption of wild food resources (Ghirardini et al. 2007; Parada et al. 2011; Łuczaj et al. 2012).

On the one hand, the decline in the consumption of wild edible plants has been attributed to several, non-mutually-exclusive, reasons. First, the decline in the consumption of wild edibles has been related to the increased accessibility of market food-products, which require less time investment than the gathering of wild plants (Menendez-Baceta et al. 2012). Second, this decline has also been related to the negative connotations of traditional activities, such as gathering.
wild edible plants, that are often considered old-fashioned and a symbol of poverty (Pieroni et al. 2005). Third, the erosion of traditional knowledge that has resulted in a lack of skills needed to identify wild edible plants and knowledge on how to process them is another of the drivers in the decline of wild plant consumption (Hadjichambis et al. 2008). Finally, some authors have argued that there is a rising concern about contamination risks at the harvesting places, which might also discourage some people to harvest wild edibles (Mesa 1996; Wehi and Wehi 2010).

On the other hand, the revival of the consumption of wild foods among certain social sectors has been influenced by the increased visibility of wild edibles in the media (Harford 2011; Łuczaj 2013; Thayer 2006) which has had a boomerang effect on the general perception of wild edible plants. Reasons for this revival are threefold: 1) the revalorization of typical products in local gastronomies, including a diversified diet that supplies a wide range of colors, flavors, and textures (Grivetti and Ogle 2000; Pardo-de-Santayana et al. 2010); 2) the use of plants adapted to local environments as a secure and sustainable source of food, since many of the most widely used wild edible plants are weeds that grow in agricultural and disturbed areas near human settlements (Tardió 2010; Turner et al. 2011); and 3) the growing awareness that wild food intake might provide health benefits, as they are potentially a source of dietary elements and serve as functional foods (Sánchez-Mata et al. 2012). For example, in comparison with conventional crops, wild foods are often richer in bioactive compounds such as essential fatty acids and secondary metabolites with antioxidant activity (Morales et al. 2012; Schaffer et al. 2005; Trichopoulou and Vasilopoulou 2000).

Those two tendencies of decline and revival of wild food consumption have been identified in previous ethnobotanical research in Central Spain, where a few species are still commonly collected while others are not collected anymore, or only rarely. For instance, recent studies conducted in several villages of Central Spain reveal that *Scolymus hispanicus* is still used by 33–38% of the rural population (Polo et al. 2009) and *Silene vulgaris* by 14–40% (Andrés 2012; Dávila 2010; García-Cervigón 2013). In these cases, the recreational motivation for gathering wild plants and appreciation of their flavors mainly explain why these two plants continue to be used in rural communities, which contrasts with the necessity that drove collection among traditional peasant societies (Aceituno-Mata 2010) and during times of food shortage, like the Spanish postwar period (Tardió et al. 2006). Other species, like *Rumex papillaris*, are no longer used in some villages. This is the case in Buitrago de Lozoya, where approximately 30% of the population used this species in the past (García-Cervigón 2013). These studies also indicate that older people clearly consume and gather more species than the younger generations, but they do not find important differences in the gendered distribution of ethnobotanical knowledge about wild edible plants (Andrés 2012; García-Cervigón 2013; Polo et al. 2009). Nevertheless, we have detected an increasing interest in wild food collection courses, books, and other outreach activities carried out by our research team among urban young people concerned with rural traditional knowledge.

As some researchers have highlighted, weedy vegetables are a potentially interesting source of healthy foods whose sustainable exploitation may be
encouraged (Hadjichambis et al. 2008). However, to achieve sustainable exploitation, innovative ways of adapting traditional practices into contemporary socioeconomic contexts are needed (Ladio et al. 1997; Turner and Turner 2008). In the framework of sustainable rural development, traditional food revitalization projects are being created. Such projects include organic farming and eco-tourism with guided routes for gathering wild plants and the commercialization of specialities made with local products in restaurants and regional markets. The emerging agroecological movements and the increased demand for organic food appear as potential niches for traditional food extraction and production systems (Gómez-Baggethun et al. 2010). However, if the demand for wild edible plants increases, their sustainable extraction becomes an issue. The sustainable exploitation of wild edible plants requires solid quantitative data on their potential yield to assess alternatives for the management of wild food plants (Cunningham 2001). With the exception of a few species (Kerns et al. 2004; Lepofsky et al. 1985; Molina et al. 2011, 2012; Tardío et al. 2011), there is a general lack of studies on the availability and yield of wild edible plants. Moreover, the potential yield of weedy wild vegetables has been poorly addressed, particularly in the Mediterranean region.

Given the interest in weed consumption for food security and food sovereignty, we study the availability and yield of 15 wild vegetables traditionally consumed in the Mediterranean region. Based on our results, we propose three different methods of sustainable exploitation of wild edible plants and assess which of the studied species are the most suitable for each alternative, according to yield and cultural factors. These results can be used in policies oriented to promote their sustainable extraction.

Materials and Methods

Wild Edible Species

Fifteen wild vegetable species were selected based primarily on their traditional use in Spain (Tardío et al. 2006) and other Mediterranean and European countries (Hadjichambis et al. 2008; Leonti et al. 2006; Łuczaj et al. 2013) and, secondarily, on their local use and natural occurrence in Central Spain, where fieldwork was conducted. Species selected belong to eight families and include twelve perennial and three annual herbs (Table 1). With the exception of Rumex papillaris, the selected species are widely distributed in the Mediterranean and European countries (Euro+Med 2012; Tutin et al. 1964–1980). The species Rumex papillaris, also known as R. thyrsiflorus subsp. papillaris (Boiss. & Reut.) Sagredo & Malag., is endemic from continental areas of the Iberian Peninsula (Castroviejo et al. 1986–2012), but can be considered a substitute of other species with a similar taste, more widely distributed and closely related, such as Rumex acetosa L. or even R. thyrsiflorus Fingerh. All the species selected are non-endangered weeds commonly found in human-disturbed habitats (Carretero 2004). Some of the species, such as Apium nodiflorum, occur in aquatic environments and swampy areas.

The aerial parts, including the basal leaf rosette or the leafy young stems, are used in most species. The bulb and the pseudostem formed by the overlapping
Table 1. Main characteristics of the wild vegetables species surveyed.

<table>
<thead>
<tr>
<th>Plant species (voucher specimen)</th>
<th>Family</th>
<th>Biotype</th>
<th>Parts used</th>
<th>Preparation</th>
<th>Taste and texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allium ampeloprasum L. (MA 852816)</td>
<td>Liliaceae (s.l.)</td>
<td>Perennial</td>
<td>Bulb and pseudostem</td>
<td>Cooked</td>
<td>Strong garlic taste</td>
</tr>
<tr>
<td>Anchusa azurea Mill. (MA 852825)</td>
<td>Boraginaceae</td>
<td>Perennial</td>
<td>Basal leaves</td>
<td>Cooked</td>
<td>Soft taste, slightly pilose texture</td>
</tr>
<tr>
<td>Apium nodiflorum (L.) Lag. (MA 852814)</td>
<td>Apiaceae</td>
<td>Perennial</td>
<td>Young leaves and stems</td>
<td>Raw in salads</td>
<td>Distinctive slight bitter taste</td>
</tr>
<tr>
<td>Beta maritima L. (MA 852817)</td>
<td>Amaranthaceae</td>
<td>Perennial</td>
<td>Basal leaves</td>
<td>Cooked</td>
<td>Soft taste</td>
</tr>
<tr>
<td>Chondrilla juncea L. (MA 852822)</td>
<td>Asteraceae</td>
<td>Perennial</td>
<td>Basal leaves</td>
<td>Cooked or raw (salads)</td>
<td>Bitter taste</td>
</tr>
<tr>
<td>Cichorium intybus L. (MA 852830)</td>
<td>Asteraceae</td>
<td>Perennial</td>
<td>Basal leaves</td>
<td>Cooked</td>
<td>Soft taste, slightly pilose texture</td>
</tr>
<tr>
<td>Foeniculum vulgare Mill. (MA 852824)</td>
<td>Apiaceae</td>
<td>Perennial</td>
<td>Young leaves and stems</td>
<td>Raw (snack, salads) or cooked</td>
<td>Aniseed taste</td>
</tr>
<tr>
<td>Papaver rhoes L. (MA 852831)</td>
<td>Papaveraceae</td>
<td>Annual</td>
<td>Young leaves and stems</td>
<td>Cooked, seldom raw in salads</td>
<td>Soft taste, slightly pilose texture</td>
</tr>
<tr>
<td>Rumex papillaris Boiss. &amp; Reut. (MA 852820)</td>
<td>Polygonaceae</td>
<td>Perennial</td>
<td>Basal leaves</td>
<td>Raw in salads</td>
<td>Acid-lemon taste</td>
</tr>
<tr>
<td>Rumex pulcher L.¹ (MA 852826)</td>
<td>Polygonaceae</td>
<td>Perennial</td>
<td>Basal leaves</td>
<td>Cooked</td>
<td>Slight acid taste</td>
</tr>
<tr>
<td>Scolymus hispanicus L. (MA 852821)</td>
<td>Asteraceae</td>
<td>Perennial</td>
<td>Central nerve of basal leaves</td>
<td>Cooked, seldom raw in salads</td>
<td>Soft taste</td>
</tr>
<tr>
<td>Silene vulgaris (Moench) Garcke² (MA 852832)</td>
<td>Caryophyllaceae</td>
<td>Perennial</td>
<td>Young leaves and stems</td>
<td>Cooked, seldom raw in salads</td>
<td>Soft taste</td>
</tr>
<tr>
<td>Silybum marianum Gaerth. (MA 852833)</td>
<td>Asteraceae</td>
<td>Annual</td>
<td>Central nerve of basal leaves</td>
<td>Cooked, seldom raw in salads</td>
<td>Soft taste</td>
</tr>
<tr>
<td>Sonchus oleraceus L. (MA 852812)</td>
<td>Asteraceae</td>
<td>Annual</td>
<td>Young leaves and stems</td>
<td>Raw in salads or cooked</td>
<td>Mild taste</td>
</tr>
<tr>
<td>Taraxacum officinale (Willd.) DC (MA 852811)</td>
<td>Asteraceae</td>
<td>Perennial</td>
<td>Basal leaves</td>
<td>Raw in salads</td>
<td>Mild bitter taste</td>
</tr>
</tbody>
</table>

¹ Rumex pulcher L. subsp. pulcher.
² Silene vulgaris (Moench) Garcke subsp. vulgaris (syn: Silene vulgaris subsp. angustifolia).
leaf bases are consumed in *Allium ampeloprasum* (Table 1). In the case of the thistles *Scolymus hispanicus* and *Silybum marianum*, the midribs of the basal leaves, known as *pencas* in Spanish, are eaten. The biotype, the part used, the local mode of preparation and consumption (from Tardío et al. 2005), and the taste and texture of the selected plants can be found in Table 1. Six species are mainly consumed raw in salads. The remaining nine species are mainly consumed cooked. Some of them are boiled with two or three changes of water to reduce their bitterness or acidity and improve their palatability.

According to nutritional studies carried out by our research group, several of the studied species are rich in bioactive compounds that might have important health benefits because of their antioxidant activity. For instance, *Rumex pulcher*, *Rumex papillaris*, and *Silene vulgaris* are rich sources of vitamin C; *Anchusa azurea* of folates; *Sonchus oleraceus* and *Chondrilla juncea* of α-tocopherol; and *Cichorium intybus*, *Beta maritima* [syn. *B. vulgaris* subsp. *maritima* (L.) Arcang.], and *Taraxacum obovatum* of phenolics and flavonoids (Morales et al. 2011; Morales 2011; Sánchez-Mata et al. 2012).

Plant identification and nomenclature follows *Flora iberica* (Castroviejo et al. 1986–2012) and *Flora Europaea* (Tutin et al. 1964–1980). Since yield variables were measured at pre-flowering stages, the species were botanically identified from leaf morphology and the remaining skeletal stems from the previous season. Voucher specimens at flowering stages were also collected and deposited at the herbarium MA (Real Jardín Botánico, CSIC, Madrid; see voucher number in Table 1).

**Study Sites**

Fieldwork was carried out in Central Spain. Mediterranean climate characterizes the territory. The highest temperatures and the longest summer drought are reached in the southeastern areas. Mean annual temperature and annual rainfall ranges from 11.0–13.5°C and 600–700 mm in the northern, western and central sites to 13.0–13.8°C and 400–500 mm in the southeastern locations (SIGA 2012). Because of its proximity to the Madrid Metropolitan Area (~5.3 million inhabitants), the landscape of the area has been largely transformed. Croplands mainly devoted to cereals, grapevines, and olive trees, represent 24.8% of the total surface of this province, contributing only 0.12% of the gross domestic product (IE 2011). The economy is mainly based on industry and services. Agriculture represents an important percentage of land uses only in the southern and eastern locations, whereas pastures and forest lands are more important in the northern and western areas. Previous research in the area suggests that traditionally 5.5% of the local wild flora species were consumed, a larger percentage than expected for a region neighboring an important major city (Aceituno-Mata 2010; Tardío et al. 2005).

The natural yields and the local availability of each species were estimated in two different sites of Central Spain. Table 2 lists the study sites, the characteristics of the sampling areas (see below), and the month of harvest. Since most species are broadly tolerant to environmental variations, and since there is a considerable range of climate, soil types, altitude, and land uses in this territory, we selected ecologically different sites. The samplings of *Beta maritima*
and *Rumex papillaris* were only conducted in locations with calcareous and non-calcareous soils, respectively, because of their specific soil preferences (Figure 1).

Most of the study sites are located in outlying villages (<10,000 inhabitants) of the province of Madrid, where the study species grow spontaneously (Figure 1). Oligotrophic soils developed on sediments from granite and sandstone are found in mountainous locations from the north (site h; 1140 m altitude), southwest (site b; 780 m), and central plains areas (site c; 690 m). The landscape in the southeastern areas is shaped by a bleak plateau with fertile plains along the course of the rivers. Eutrophic soils developed on basic rocks, such as limestone, marl, or gypsum, are found in these locations (sites a, d, e, f, i; 450–675 m). Finally, one site is located on calcareous soils in the neighboring province of Guadalajara (site g; 876 m).

### Sampling Areas and Periods

Our sampling areas were adjusted to the microdistribution of the species at the study sites—we adjusted the areas to those places where the species actually grow. We differentiated four sampling areas: 1) cultivated lands (olive groves, vineyards, cereal crops, and orchards); 2) uncultivated lands (fallow lands, neglected lands, and pastures); 3) ruderal areas (roadsides, country tracks, and paths); and 4) aquatic environments (streams and irrigation ditches near farmlands).

The microdistribution of the species at the study sites and, consequently, the sampling areas (see Table 2) varied depending on land uses and management practices. Figure 2 shows a schematic illustration of the four types of sampling areas and a representative picture of each. In cultivated lands with reduced herbaceous vegetation cover (such as olive groves and vineyards) the sampling area was restricted to the boundaries of the cultivated plot. In cultivated lands

### Table 2. Study sites and harvest conditions of the wild vegetables surveyed.

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Site</th>
<th>Sampling areas</th>
<th>Harvest month</th>
<th>Site</th>
<th>Sampling areas</th>
<th>Harvest month</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Allium ampeloprasum</em></td>
<td>a</td>
<td>UL, RA</td>
<td>March</td>
<td>b</td>
<td>CL, RA</td>
<td>March</td>
</tr>
<tr>
<td><em>Anchusa azurea</em></td>
<td>b</td>
<td>CL, RA</td>
<td>March</td>
<td>i</td>
<td>CL, UL, RA</td>
<td>April</td>
</tr>
<tr>
<td><em>Apium nodiflorum</em></td>
<td>f</td>
<td>AE</td>
<td>April</td>
<td>i</td>
<td>AE</td>
<td>April</td>
</tr>
<tr>
<td><em>Beta maritima</em></td>
<td>a</td>
<td>CL, UL, RA</td>
<td>March–April</td>
<td>e</td>
<td>CL</td>
<td>April</td>
</tr>
<tr>
<td><em>Chondrilla juncea</em></td>
<td>c</td>
<td>UL, RA</td>
<td>April</td>
<td>g</td>
<td>UL, RA</td>
<td>May</td>
</tr>
<tr>
<td><em>Cichorium intybus</em></td>
<td>a</td>
<td>CL, UL, RA</td>
<td>March</td>
<td>c</td>
<td>UL, RA</td>
<td>April–May</td>
</tr>
<tr>
<td><em>Foeniculum vulgare</em></td>
<td>c</td>
<td>UL, RA</td>
<td>May</td>
<td>f</td>
<td>CL, UL, RA</td>
<td>May</td>
</tr>
<tr>
<td><em>Papaver rhoas</em></td>
<td>a</td>
<td>CL, UL, RA</td>
<td>March–April</td>
<td>c</td>
<td>UL, RA</td>
<td>April</td>
</tr>
<tr>
<td><em>Rumex pulcher</em></td>
<td>a</td>
<td>CL, UL, RA</td>
<td>March–April</td>
<td>c</td>
<td>UL, RA</td>
<td>April</td>
</tr>
<tr>
<td><em>Scorpiurus hispanicus</em></td>
<td>c</td>
<td>UL, RA</td>
<td>April–May</td>
<td>d</td>
<td>CL, UL, RA</td>
<td>April–May</td>
</tr>
<tr>
<td><em>Silene vulgaris</em></td>
<td>b</td>
<td>CL, RA</td>
<td>March</td>
<td>i</td>
<td>CL, RA</td>
<td>April</td>
</tr>
<tr>
<td><em>Silybum marianum</em></td>
<td>a</td>
<td>CL, UL, RA</td>
<td>March–April</td>
<td>c</td>
<td>UL, RA</td>
<td>April–May</td>
</tr>
<tr>
<td><em>Sonchus oleraceus</em></td>
<td>a</td>
<td>CL, UL, RA</td>
<td>March–April</td>
<td>b</td>
<td>CL, RA</td>
<td>March</td>
</tr>
<tr>
<td><em>Taraxacum obovatum</em></td>
<td>c</td>
<td>UL, RA</td>
<td>April</td>
<td>i</td>
<td>CL, UL</td>
<td>April</td>
</tr>
</tbody>
</table>

1 Study sites: a Alcalá de Henares; b Cadalso de los Vidrios; c Cantoblanco-Madrid; d Fuentidueña de Tajo; e Morata de Tajuna; f Perales de Tajuna; g Pioz; h Valdemorillo; i Villar del Olmo.
2 Sampling areas: CL cultivated lands; UL uncultivated lands; RA ruderal areas; AE aquatic environments.
with an extensive herbaceous cover, however, the entire plot was sampled, as well as in fallow lands, neglected lands, and pastures. In the case of roadsides or paths, the plants could only be sampled at the margins. In aquatic environments, the samples were taken only in the water course and damp areas in the margins. All these sampling areas can be considered potential gathering places since they are similar to those shown by the informants in previous ethnobotanical studies (Aceituno-Mata 2010; Tardío et al. 2005). They are located in the vicinity of the villages, generally near agricultural areas where weedy vegetables are abundant.

To obtain a realistic estimate of the species’ edible yields, we only selected areas where pesticides or herbicides had not been sprayed. However, the streams and irrigation ditches where *Apium nodiflorum* naturally occurs at site f were occasionally cleaned and herbicides were applied. Production was not quantified at this site in 2008 because the scarce plant material remaining after herbicide application was not suitable for human consumption.

All the species were sampled in spring, from March to May (see Table 2), and collected in their optimal period of consumption according to previous ethnobotanical research (Tardío et al. 2005). The optimal period was defined as the time before blooming, when the leaves and stems are still tender but have a size large enough to be gathered. Most plants could be gathered in the middle of spring (April), whereas the optimal growing stage of some species was reached in early (e.g., *Allium ampeloprasum*) or late spring (e.g., *Scolymus hispanicus*). Harvesting dates also depended on the geographical area and the annual meteorological conditions. For example, *Rumex papillaris* was harvested in March at site b (780 m altitude) and almost two months later at site h (1140 m).
Estimation of Individual Plant Yields

Individual plant yields of weedy vegetables were estimated during two (2007–2008) or three (2007–2009) consecutive years. Basic ecological techniques were applied following Cunningham (2001). The species were first divided into two groups according to their growth forms. The first group, named non-clonal species, includes species in which individuals can be easily distinguished. This group contains perennial and annual species in which the aerial part can be assumed to have developed from a single “rooted unit.” Within this group, a minimum of 25 randomly selected individuals per species were collected at each site. The fresh and healthy-appearing edible part was immediately weighed with a field scale. The second group, named clonal species, includes perennial species which grow forming clumps, such as Apium nodiflorum, Silene vulgaris, Rumex pulcher and Rumex papillaris. These herbs usually produce clonal offspring by means of vegetative growth. They have stoloniferous stems, branching rhizomes or roots, and dense rosettes or patches that may have originated from one or more “rooted units.” For clonal species, we collected and weighed the edible

Figure 2. A schematic illustration of the sampling areas (striped area) according to the presence of the species (marked with black dots) in cultivated lands (CL), uncultivated lands (UL), ruderal areas (RA), and aquatic environments (AE) and a representative photograph of each area: CL, olive grove with herbaceous cover; UL, neglected land; RA, pathway; AE, a stream nearby farmlands.
plant material from at least 25 quadrats of 20 × 20 cm (0.04 m²) randomly placed into the clumps formed by these species. Although yield data are not entirely comparable, we used a quadrat of 20 × 20 cm because this area approximately covers the same surface as the single rosette of several species with clearly differentiated individuals.

Non-destructive methods of collection were applied to perennial herbs, except for the geophyte *Allium ampeloprasum*, whose bulb was dug out with a hoe. The basal rosette of leaves and the leafy young stems of the hemicryptophyte species were harvested with scissors, leaving the root or rhizome intact without damaging its ability to resprout. The leaf blade of the thistles *Scolymus hispanicus* and *Silybum marianum* was eliminated before weighing. Leaves were peeled in the same way they would be prepared for eating, leaving only the edible part, the midrib and petiole. The leafy young stems of *Silene vulgaris* were collected by pinching and cutting them with the fingers. The aerial parts were harvested in annual species.

**Estimation of Plant Density**

The local availability of the species was assessed in terms of plant density through a minimum of 25 randomly located transects of 25 × 2 m. The UTM coordinates of transects, from start to finish, were recorded and represented on master maps. Fieldwork was limited to the sampling areas previously described (see Figure 2).

Sampling took place between June and August, when we could easily identify and count the individuals thanks to the presence of flowers. In some cases, sampling was performed in spring, before crop lands were ploughed to remove weeds. Different procedures were used according to species growth (clonal vs. non-clonal) and biotype (perennials vs. annuals). For non-clonal species, we counted the number of individuals in each transect. For clonal species, we estimated plant cover by counting the number of 20 × 20 cm quadrats per transect occupied by the plants. For perennial species, plant density was estimated only in 2008 for the whole period, assuming that it will not significantly increase or decrease throughout the study years. For annual species we estimated plant density over a two year period (2008 and 2009).

**Estimation of the Production per Hectare**

The individual yield and plant density values herein obtained were combined to ascertain the approximate production rate per hectare. Production per hectare was calculated by multiplying the average individual yield data by the average plant density of the species, assuming that all the plants counted in transects would reach harvestable sizes.

**Data Analysis**

Production data are expressed as fresh weight at harvest. Mean value ± standard error (SE) of the three variables considered (individual plant yield, plant density, and production per hectare) is given for all the samples. Each sample comprises the dataset (n ≥ 25) obtained per species, year, and site. Since yield data were not normally distributed (Kolmogorov-Smirnov test) and there was no variance homogeneity among groups (Levene test), we used
non-parametric tests (Kruskal-Wallis and Mann-Whitney U test, applying the Bonferroni correction when multiple sets of data were compared). Intra-sample variability was also assessed with the coefficient of variation (CV).

In order to explore whether yield varied with environmental factors, we used correlation analysis. Monthly and accumulated precipitation and mean temperature from January to May were considered, as well as the altitude at the study sites. Data were taken from the meteorological stations nearest to each site (between 0–15 km of distance; 7 km on average) and provided by the Spanish Meteorological State Agency (AEMET). Given the limited number of samples (4–6 samples per species) this analysis was exclusively used in an exploratory way, since long-term research would be necessary for studying the real influence of such factors on yield.

Results and Discussion

Individual Plant Yield

Yield estimates of the wild greens surveyed are summarized in Table 3. The mean edible production of non-clonal species ranged from 7.8 g per plant in *Taraxacum obovatum* (year 2008, site 1) to 458.8 g per plant in *Beta maritima* (year 2007, site 1). Yield estimates of clonal species varied from 15.8 g per quadrat in *Silene vulgaris* (year 2008, site 2; equivalent to 395 g m\(^{-2}\)) to 201.8 g in *Apium nodiflorum* (year 2008, site 2; 5,045 g m\(^{-2}\)). Overall, the highest yield rates were found in *Beta maritima*, *Foeniculum vulgare* and *Silybum marianum*, and the lowest yield rates were found in *Allium ampeloprasum*, *Taraxacum obovatum* and *Silene vulgaris*.

Although species yield values were obtained from one collection per season, according to our own cultivation experiments and those of other authors (Casco 2000), several species in our sample, such as *Cichorium intybus*, *Rumex pulcher* or *Silene vulgaris*, could tolerate two or even three harvests in a season when they are cultivated. Thus, for these vegetables, the values presented here clearly underestimate potential yields.

There were remarkable differences among samples grown in different sites or years (Table 3). Four different variation patterns were found: 1) the production fluctuated between years in a proportional way at both sites (Figure 3A); 2) yield variations were different at each site (Figure 3B); 3) production fluctuated annually without significant between-site differences (Figure 3C); and 4) between-year and between-site differences did not show a clear pattern (Figure 3D).

In order to explore whether yield varied with environmental factors, we performed a correlation analysis with monthly and accumulated precipitation, mean temperature, and altitude. When significant, correlation coefficients are shown in Figure 3. In some species, such as *Sonchus oleraceus*, *Allium ampeloprasum* and *Scolymus hispanicus*, yields were positively correlated with monthly precipitation at harvest time, whereas in others, such as *Beta maritima*, a significant correlation was found with accumulated rainfall from January to March. Yield fluctuations in other species, such as *Cichorium intybus*, were correlated with mean temperature. In *Rumex papillaris*, the production was negatively correlated with altitude. Additionally, in the first two groups...
Table 3. Natural edible production of the surveyed species in descending order of yield (mean ± SE; g per plant in non-clonal species and g per 20 × 20 cm quadrat in clonal species).

<table>
<thead>
<tr>
<th>Plant species</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>Total average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 1</td>
<td>Site 2</td>
<td>Site 1</td>
<td>Site 2</td>
</tr>
<tr>
<td><strong>Non-clonal species</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta maritima</td>
<td>458.8 ± 54.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>326.9 ± 60.4&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>170.8 ± 19.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>175.1 ± 18.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Foeniculum vulgare</td>
<td>327.1 ± 60.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>328.5 ± 45.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>191.0 ± 24.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>200.4 ± 13.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Silybum marianum</td>
<td>300.1 ± 53.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>315.7 ± 44.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>194.2 ± 41.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>278.1 ± 74.6&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cichorium intybus</td>
<td>104.7 ± 10.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>210.9 ± 30.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>55.8 ± 4.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>155.8 ± 23.3&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Anchusa azurea</td>
<td>N/A</td>
<td>139.1 ± 19.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>167.2 ± 29.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>141.8 ± 11.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Papaver rhoas</td>
<td>30.3 ± 2.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.3 ± 7.0&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>95.9 ± 8.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>83.1 ± 32.0&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Scolymus hispanicus</td>
<td>85.4 ± 14.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>32.4 ± 5.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>41.1 ± 4.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.7 ± 9.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chondrilla juncea</td>
<td>37.4 ± 6.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.3 ± 2.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>67.4 ± 7.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.8 ± 0.8&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sonchus oleraceus</td>
<td>49.0 ± 11.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N/A</td>
<td>18.7 ± 2.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.9 ± 2.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Allium ampeloprasium</td>
<td>16.3 ± 1.5&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>14.5 ± 0.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>8.5 ± 0.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.4 ± 2.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Taraxacum obovatum</td>
<td>16.5 ± 1.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.7 ± 2.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.8 ± 0.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.1 ± 0.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Clonal species</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apium nodiflorum</td>
<td>101.0 ± 8.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N/A</td>
<td>N/A</td>
<td>201.8 ± 15.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rumex pulcher</td>
<td>105.2 ± 8.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>92.3 ± 5.4&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>115.7 ± 9.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>80.1 ± 6.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rumex papillaris</td>
<td>114.8 ± 11.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>60.7 ± 5.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>121.4 ± 8.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.7 ± 4.8&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Silene vulgaris</td>
<td>24.9 ± 1.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.9 ± 1.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.6 ± 1.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.8 ± 1.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

N/A = Not Applicable.

<sup>a,b,c,d</sup> = The same superscript letters following yield measurements in each row indicate means ± SE cannot be distinguished statistically. Different superscript letters indicate the yields are statistically different. Pairs of data were compared using Mann-Whitney U test (p < 0.05); multiple sets of data were initially compared using Kruskal-Wallis (p < 0.05). Pairwise differences were then determined using a Bonferroni correction.
(Figure 3A and B) in which the highest yield rates were recorded at the same site over the study years, other factors, such as soil characteristics (e.g., pH, texture, nutrients), land uses (e.g., ploughed-unploughed agricultural lands), or even the presence of local ecotypes of the same species, might have influenced yields.

Regarding intra-sample variability, the species with the highest levels (CVs > 90%) were *Papaver rhoeas*, *Scolymus hispanicus*, *Silybum marianum* and *Sonchus oleraceus*. Under the same environmental growth conditions, the yield of these species varied widely, possibly because of microhabitat characteristics. Steady productions (CVs < 50%) were found in *Apium nodiflorum*, *Rumex papillaris*, *Rumex pulcher*, *Silene vulgaris* and *Taraxacum obovatum*, mostly clonal species, in which low genetic variability would be expected.

**Plant Density**

Estimates of plant density are presented in Table 4. Density ranged between 2,000–15,000 plants ha\(^{-1}\) and quadrats ha\(^{-1}\) in both clonal and non-clonal herbs. Considerably lower values were found in *Scolymus hispanicus* (500 plants ha\(^{-1}\)), in
Table 4. Plant density of perennial (2008) and annual (2008 and 2009) species at the sampling areas (mean ± SE; individuals ha\(^{-1}\) in non-clonal species, and number of 20 \(\times\) 20 cm quadrats ha\(^{-1}\) occupied by the plant in clonal species).

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Clonal species</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumex pulcher</td>
<td>14,570 ± 2,913(^{a})</td>
<td>3,593 ± 812(^{b})</td>
<td>-</td>
<td>-</td>
<td>9,435 ± 1,733</td>
</tr>
<tr>
<td>Silene vulgaris</td>
<td>7,623 ± 1,113(^{a})</td>
<td>5,821 ± 1,086(^{a})</td>
<td>-</td>
<td>-</td>
<td>6,757 ± 782</td>
</tr>
<tr>
<td>Rumex papillaris</td>
<td>3,857 ± 1,046(^{a})</td>
<td>5,773 ± 1,690(^{b})</td>
<td>-</td>
<td>-</td>
<td>4,728 ± 956</td>
</tr>
<tr>
<td>Non-clonal species</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allium ampeloprasum</td>
<td>25,350 ± 7,964(^{a})</td>
<td>11,552 ± 2,966(^{a})</td>
<td>-</td>
<td>-</td>
<td>15,474 ± 3,189</td>
</tr>
<tr>
<td>Chondrilla juncea</td>
<td>8,779 ± 1,206(^{a})</td>
<td>6,267 ± 1,138(^{a})</td>
<td>-</td>
<td>-</td>
<td>7,687 ± 850</td>
</tr>
<tr>
<td>Foeniculum vulgare</td>
<td>2,150 ± 588(^{a})</td>
<td>11,400 ± 1,757(^{a})</td>
<td>-</td>
<td>-</td>
<td>6,513 ± 1,085</td>
</tr>
<tr>
<td>Anchusa azurea</td>
<td>1,061 ± 265(^{a})</td>
<td>5,907 ± 830(^{b})</td>
<td>-</td>
<td>-</td>
<td>3,984 ± 591</td>
</tr>
<tr>
<td>Cichorium intybus</td>
<td>4,237 ± 592(^{a})</td>
<td>2,914 ± 635(^{b})</td>
<td>-</td>
<td>-</td>
<td>3,676 ± 439</td>
</tr>
<tr>
<td>Beta maritima</td>
<td>2,371 ± 469(^{a})</td>
<td>5,054 ± 1,132(^{b})</td>
<td>-</td>
<td>-</td>
<td>3,412 ± 544</td>
</tr>
<tr>
<td>Scolymus hispanicus</td>
<td>542 ± 82(^{a})</td>
<td>537 ± 167(^{a})</td>
<td>-</td>
<td>-</td>
<td>540 ± 84</td>
</tr>
<tr>
<td>Papaver rhoes</td>
<td>15,638 ± 4,039(^{ab})</td>
<td>9,911 ± 4,047(^{ab})</td>
<td>17,129 ± 2,214(^{a})</td>
<td>6,825 ± 2,361(^{b})</td>
<td>13,704 ± 1,751</td>
</tr>
<tr>
<td>Silybum marianum</td>
<td>1,216 ± 316(^{a})</td>
<td>2,186 ± 1,041(^{b})</td>
<td>8,560 ± 1,377(^{b})</td>
<td>N/A</td>
<td>4,500 ± 772</td>
</tr>
<tr>
<td>Sonchus oleraceus</td>
<td>3,386 ± 667(^{a})</td>
<td>4,133 ± 1,030(^{b})</td>
<td>2,000 ± 727(^{a})</td>
<td>4,021 ± 768(^{b})</td>
<td>3,523 ± 415</td>
</tr>
</tbody>
</table>

\(N/A\) = Not Applicable.

\(a,b\) = The same superscript letters following density measurements in each row indicate means ± SE cannot be distinguished statistically. Different superscript letters indicate the densities are statistically different. Pairs of data were compared using Mann-Whitney U test (\(p<0.05\)); multiple sets of data were initially compared using Kruskal-Wallis (\(p<0.05\)). Pairwise differences were then determined using a Bonferroni correction.
agreement with previous studies (Polo et al. 2009). Conversely, *Allium ampeloprasum* attained the highest rates (11,000–25,000 plants ha$^{-1}$). Results reveal a wide gradient on plant density values, from sparse to high-density distributions; as with plant yields, some species displayed large variation in plant density between sites, especially in *Foeniculum vulgare* and *Rumex pulcher*. Intra-species variation in plant density was possibly influenced by local differences in soil characteristics and land use. In *Taraxacum obovatum* and *Apium nodiflorum*, plant density was not estimated because the natural microdistribution of these species at the study sites was limited or it was reduced by herbicide application, as previously mentioned in *Apium nodiflorum* at site f. Accordingly, the minimum number of transects required for sampling estimates was not reached ($n$ < 25 transects).

Plant density in annual herbs that were sampled in two different years ranged from 1,200 plants ha$^{-1}$ in *Silybum marianum* to 17,000 plants ha$^{-1}$ in *Papaver rhoeas* (Table 4). Between-site differences were only found in *Papaver rhoeas* in 2009, whereas the annual yields of *Sonchus oleraceus* remained steady over the two years of study. However, the annual availability of *Silybum marianum* fluctuated considerably and in one instance even dropped below the minimum values required for sampling estimates ($n$ < 25 transects). The total surface occupied by this thistle at site c was very small and, consequently, the total amount of edible plant material available in this area is also very low. In contrast to perennials, plant abundance of annual herbs may vary considerably over time since their seeds can remain in a dormant state for long periods and germinate only under suitable environmental conditions (Booth et al. 2003).

Plant density of the surveyed wild vegetables was found to be considerably high in most cases, suggesting that the sampling areas can generally provide prolific quantities of wild food resources. As we observed in the course of fieldwork, management practices like deep ploughing and herbicide spraying caused reversible short-term modifications in plant distribution. The abandonment of traditional agricultural activities has also led to the disappearance of potential habitats, limiting the availability of these plants, as previously recorded for *Scolymus hispanicus* (Polo et al. 2009). In some potential habitats, such as vacant building plots, plants have been definitely removed. Those observations dovetail with local perception that wild food plants are less abundant now than 50 years ago (Tardío et al. 2005), specifically for the species *Scolymus hispanicus, Silene vulgaris, Rumex papillaris* and *Chondrilla juncea* (Aceituno-Mata 2010), although there are no quantitative ecological data for an adequate comparison. The spatial distribution of plants is very important for gatherers, since the harvesting effort depends not only on the density in a certain place but also on the total abundance of plants available in the area (Polo et al. 2009).

Modern agricultural practices such as tractor ploughing affect not only the plant distribution but also the edible portion of the plants. For example, *Chondrilla juncea* or *Cichorium intybus* collectors preferred the blanched shoots which sprouted in ploughed lands because they found these plants more tender and less bitter, with a taste that they associate with the modern “witloof” or “Belgian endive” (Tardío et al. 2005; Tardío 2010). Today, due to modern agricultural practices, these species commonly grow away from farmlands and they do not develop these blanched shoots.
Production per Hectare

The estimated production per hectare of each weedy vegetable is shown in Figure 4. There was a wide variation in the yields of the plants at the two sites surveyed, mainly due to differences in plant density figures. At the sampling areas, and in descending order of yield, a total of 1,800 kg ha\(^{-1}\) (total average values) of *Foeniculum vulgare*, 700–1,000 kg ha\(^{-1}\) of *Beta maritima*, *Rumex pulcher*, *Papaver rhoeas* and *Silybum marianum*, and of 80–400 kg ha\(^{-1}\) for the remaining species could be obtained. The lowest yields (30 kg ha\(^{-1}\)) were found in *Scolymus hispanicus*. However, according to several ethnobotanical studies, this thistle is one of the most appreciated wild greens and it is still collected nowadays (Aceituno-Mata 2010; Polo et al. 2009; Tardío et al. 2006).

Alternatives for Traditionally Consumed Wild Vegetables

In this section, we discuss the viability of a sustainable exploitation of wild vegetables. Sustainable exploitation depends mainly on two factors: 1) natural availability; and 2) consumer demand. Because of the different densities and yields in the examined species and because of the different preferences of gatherers, it is unlikely that one type of management is suitable for all species. Therefore, three likely scenarios for sustainable harvesting have been considered: 1) organic farming; 2) harvesting of wild plants for commercial purposes; and 3) harvesting of wild plants for domestic consumption. In the light of the results obtained in this paper, we discuss how the species studied could fit into these three scenarios.
Organic Farming

Wild edible plants are a good reservoir of potential new crops for a specialized market (Turner et al. 2011). Indeed, some examples of “new” vegetables are found among wild plants with deep roots in Mediterranean food traditions, such as rocket salads (Erucá vesicaria [L.] Cav. and Diplotaxis tenuifolia [L.] DC) and watercress (Rorippa nasturtium-aquaticum Hayek). They are an interesting case of recent crop domestication in which the favorable combination of positive experience (sensory component of acceptance) and information (local gastronomy, health promotion) have contributed to successfully spread the use of these species (D’Antuono et al. 2009).

Cultivation under organic conditions might be a viable alternative for those species that may be more prone to overexploitation, for example because their low natural availability may not satisfy the potentially increasing demand. This is the case of culturally important species, especially those which showed low production rates, such as Scolymus hispanicus and Silene vulgaris. Both species are currently collected from the wild and sold in local markets and restaurants (Baraño and Soveral 2010; Tardío 2010), where a traditional dish using those species can cost 10 € (personal observations in the city of Madrid, 2012). The agronomic potential of these species has been previously studied (Alarcón et al. 2005; García et al. 2002). Scolymus hispanicus is considered a neglected crop (Hernández-Bermejo and León 1992) and it is currently a minor crop cultivated in southern Spain (Soriano 2010). Moreover, given their low natural density, gathering a considerable amount of thistles is a very time-consuming activity.

Requirements of seeds and seedlings of wild plants, as well as labor costs and productivity, are not well known. However, cultivation experiments designed to explore the agronomic feasibility of several of the species studied are currently being conducted by our research group. Additionally, technical information on organic farming, including processing and organic certification of wild vegetables, is available from previous research, such as the pilot projects conducted in western and southern Spain (Casco 2000; Fernández and López 2005). According to these experiments and based on their nutritional profiles (Morales et al. 2012; Sánchez-Mata et al. 2012), other candidates for cultivation could be Rumex pulcher, Anchusa azurea, Allium ampeloprasum, Silybum marianum, Cichorium intybus and Chondrilla juncea, although they should be subject to sensory evaluation by panelists in order to ensure consumer acceptance. In addition, the production of Apium nodiflorum in a similar way to watercress, by hydroponics or aquaculture, may avoid the pollution risk that this aquatic plant is exposed to by the use of pesticides or the presence of pastoral activity in the area.

Wild Gathering for Commercial Purposes

Sustainable harvesting of wild vegetables might be encouraged as a use of biodiversity which potentially offers social benefits to local communities (Menendez-Baceta et al. 2012). Weeds are fast-growing species that reproduce easily and, even in low-density perennials such as Scolymus hispanicus, an appropriate harvesting procedure allows continued plant growth. Such practices in harvesting leafy vegetables that were conducted by our informants include
leaving the subterranean organs of perennials intact and collecting fewer but larger specimens (Aceituno-Mata 2010). Other good practices include allowing the populations to produce seed, preventing the plants from being exhausted due to a repeated collection of the same individuals, and not gathering isolated individuals (Thayer 2006).

The collection of abundant wild food resources can be turned into a commercial activity to promote rural development. Species with high yields that are culturally appreciated such as Allium ampeloprasum, Chondrilla juncea, Beta maritima, Rumex papillaris, Foeniculum vulgare, Silybum marianum, and Sonchus oleraceus (Aceituno-Mata 2010; Tardío et al. 2005) are good candidates for wild collection with commercial purposes. Although the collection of Allium ampeloprasum might be considered destructive, our experience shows that many small bulbs produced around the central bulb remain in the collecting place. Moreover, wild populations also include smaller individuals that are not selected by the gatherers, allowing its self-regeneration.

Wild food harvesting could be developed in the framework of the organic market and sustainable harvest certification in order to assure sustainability and food quality (Müller 2009). Organic wild collection is a very broad concept which encompasses food resources collected in pastures, uncultivated lands, and other areas of the agriculture landscape (IFOAM 2006). Organic certification can be applied to wild harvested plants, as provided in legal organic regulations at the regional (CAEM 2010) and international (e.g., EU Regulations EEC 834/07 and 889/08) scales. Likewise, many private organic standards have arisen that have additional requirements for wild harvesting (e.g., Certification of Environmental Standards [CERES] in Germany; Ekologisk Produktion Certifierad [KRAV] in Sweden; Bio-Suisse in Switzerland), as well as others focused on sustainable harvest certification of wild products in a broader sense, including other uses apart from food (FairWild Foundation 2010).

All these certification systems could foster safe and appropriate marketing of wild vegetables as fresh or processed products. In fact, recent changes in market demands are influencing the reevaluation of wild foods, which are served in local restaurants as unique traditional delicacies. The wild food and drink sector seems to be a successful, profitable, and expanding one. More than 300 wild products are currently being produced for the global organic market, including medicinal and aromatic plants, nuts, fruits, and mushrooms collected in forested areas (IFOAM 2006). Because of the contamination risks that weedy vegetables are potentially exposed to, such as car exhaust, agrochemicals, and other sources of pollution, the specific standards for the collection of weedy vegetables growing on agricultural areas need to be more extensively developed in order to avoid unsafe consumption of wild edibles. In this way, the combination of organic farming and wild collection of weedy edibles in the same plots could be an interesting alternative to guarantee food safety.

**Wild Collection for Self-Consumption**

Generally, small amounts of plant material are required to fulfill domestic harvesting needs. According to our yield and plant density estimations, the ruderal species herein studied are suitable to be harvested regularly for self-consumption without endangering their populations. Those species have been
traditionally collected and their populations do not seem to have suffered from this exploitation. Therefore, wild edibles could be harvested as useful resources in the effort to achieve food security and sovereignty. The maintenance of traditional practices, like gathering wild plants, has shown to operate as an important reservoir of useful knowledge, preventing its erosion. In central Spain, wild edibles have been an important dietary supplement in springtime, coinciding with a seasonal period of scarcity of cultivated vegetables (Aci-tuno-Mata 2010). Nowadays, these practices can be interesting for food security as a buffer against times of food shortage or food crisis, such as the famine periods that happened in some parts of Europe in the nineteenth and twentieth centuries (Łuczaj et al. 2012). Although the economic potential of foraging wild edibles is unknown, it could be significant for domestic economies, as suggested by the economic benefits of Spanish home gardens (Reyes-García et al. 2012).

Vogl-Lukasser et al. (2010) report that some weeds spontaneously emerging in Austrian Alpine home gardens are tolerated because they are seen as an opportunity for increasing the number of useful plants and saving money. In home gardens, foraging wild edibles could also be transformed into a valuable environmental educational tool to promote traditional ecological knowledge and the conservation of wild species and their associated habitats (Sanderson and Prendergast 2002). Since wild foraging is not risk-free, however, competent identification of plants should be encouraged, especially for urban or untrained collectors, in order to avoid accidental poisoning by toxic look-alike species (Colombo et al. 2010).

Conclusion

This work aims to contribute to the knowledge and valorization of traditionally consumed wild vegetables. Despite their great nutritional interest, wild vegetables are still an undervalued food resource and very little is known about their production and sustainable exploitation. As far as we know, this paper provides the first quantitative data on the natural yields and availability of 15 Mediterranean wild green vegetables. Due to the great heterogeneity of the species with respect to life and growth forms, we have developed a basic yield evaluation methodology for wild vegetables that can be applied in other surveys.

According to local people, changes in land uses and management practices have diminished in some cases the local availability of these plants, especially due to the abandonment of traditional agricultural practices, contamination risks, and the urbanization of agricultural lands. Nevertheless, the edible yield of these plants was found to be considerably high in most cases, revealing the potential of traditional wild vegetables to increase food diversity. Some of the most appreciated of the still-collected species, such as Scolymus hispanicus and Silene vulgaris, showed low production rates. This finding suggests that species yield does not drive the selection of wild edible plants.

Traditional harvesting offers sociocultural, economic, and ecological benefits to local communities. It also contributes to the conservation of biocultural diversity and promotes cultural empowerment to resist acculturation. Moreover,
commercial wild collection and organic farming are feasible alternatives that can promote food quality and rural economic growth. Natural yields of wild edible plants can be compared with those obtained under agricultural conditions. Additionally, consumer acceptance should be assessed by sensory evaluation panels when considering their interest as potential new crops.

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References Cited


Harford, R. 2011. Eat Weeds. Wild Food Guide to the Edible Plants of Britain. Available at:


