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Research Article

FLOWERING PLANTS PREFERRED BY NATIVE WILD BEES (HYMENOPTERA, APOIDEA, APIFORMES) IN THE ALGERIAN LITTORAL REGION

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ABSTRACT

This study considered the plant floral resources visited by native wild and honey bees in Algiers (northern Algeria). Three botanical families accounted for almost 2/3 of all visits: Asteraceae (44.1%), Boraginaceae (15.3%) and Brassicaceae (13%). Plants in other families were visitedless frequently (e.g.Ranunculaceae (0.1%)). At the species level, the most frequently visited plant was *Anchusa azurea* (Boraginaceae), reaching 15.2% of the total bee visitation. Our work showed that *Apis mellifera* Linnaeus, 1758 is, typically, a polylectic species and that the majority of solitary bees exhibited the more specialised trait of oligolectics. The narrowest trophic niche varied between 0.01 and 0.06 bits for *Halictus rufipes* (Fabricius, 1793), *Halictus scabiosae* (Rossi, 1790) (Halictidae), *Osmia pinguis* Pérez, 1895 and *Osmia tricornis* Linnaeus, 1811 (Megachilidae).

Key-words: Wild bees, floral choices, natural habitat, northern of Algeria.

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1. INTRODUCTION

1.1. Importance of wild bees

Bees are essential for the successful sexual reproduction of many plants [1,2]. Probably, their most important activity, in terms of benefits to humans, is the pollination of natural vegetation [2]. Bees, and their role in pollination, have been studied from various points of view in Europe [3-10], Asia [11-14] and North America [15-17]. In the Maghreb, especially Algeria, few studies on wild bees have been published up to now. The works conducted so far are those of [18-24], and were based on small areas of the country. After them, a long time passed before the publication of new works dealing with particular groups [25,26]. or natural floral resources [27-32].

1.2. Objectives

The interactions between plants and bees have been studied by several authors in semi-natural and agricultural environments [33-38]. The present study concerns the north of Algeria (particularly the Algiers region) and its objectives were (i) to determine the floral choices shown by native wild and domesticated bees, and (ii) to provide an estimate of their food specialization in order to find out the degree of concentration of the apoids on certain botanical families and species in their natural habitats during the spring and the end of the winter.

2. RESULTS AND DISCUSSION

In our study, 37 plant species were used as a forage resource by bees (Table 1). *Anchusa azurea* was the most frequently visited one, accounting for 15.2% of the number of visits in the study area. It was followed by *Galactites tomentosa* with a rate of 12.1% and *Papaver rhoeas* with 9.2%. On the other hand, *Sinapis arvensis*, whose rate of visitation did not exceed 8.6 %, attracted the highest number of species (34), which represents a third of all the bee species found in the study. Nine plant species were visited by a single bee species.

When visitation is studied at the plant family level, we find that, out of the 15 plant families visited (Table 1, Figure 1), four accounted for more than 87% of all the bee visits. The most frequently visited plant families in our study (in descending order) were: Asteraceae (44.1 % of visits), Boraginaceae (15.3 %), Brassicaceae (13.0 %) and Papaveraceae (9.2 %). The

Asteraceae were visited by 72.7% of the species of Halictidae, 68.9% of the Megachilidae, 67.2% of the Apidae and 29.9% of the Andrenidae. 42.0% of all visits to Boraginaceae were made by Apidae and 19.6% by Andrenidae. These families were followed by Megachilidae with 14.8% and Halictidae, with the lowest rate (2.8%). The Brassicaceae were visited by Andrenidae with a high visitation rate of 36.0 %, followed by Apidae (24.4%) and Halictidae (11.8%). Megachilid bees were infrequent visitors, with a visitation rate of 3.3%. Other plant families were visited by some families of Apoidea, such as Fabaceae and Primulaceae.

Apidae accounted for the greatest number of flower visits (352 visits) which is higher than for other bee families (Table 2). They were followed by Halictidae with 110 visits and Andrenidae with 97. The Megachilidae made only 61 visits. 36 plant species were visited as a whole. The Apidae visited 26 plant species, the Andrenidae 21, the Halictidae 16 and the Megachilidae 12.

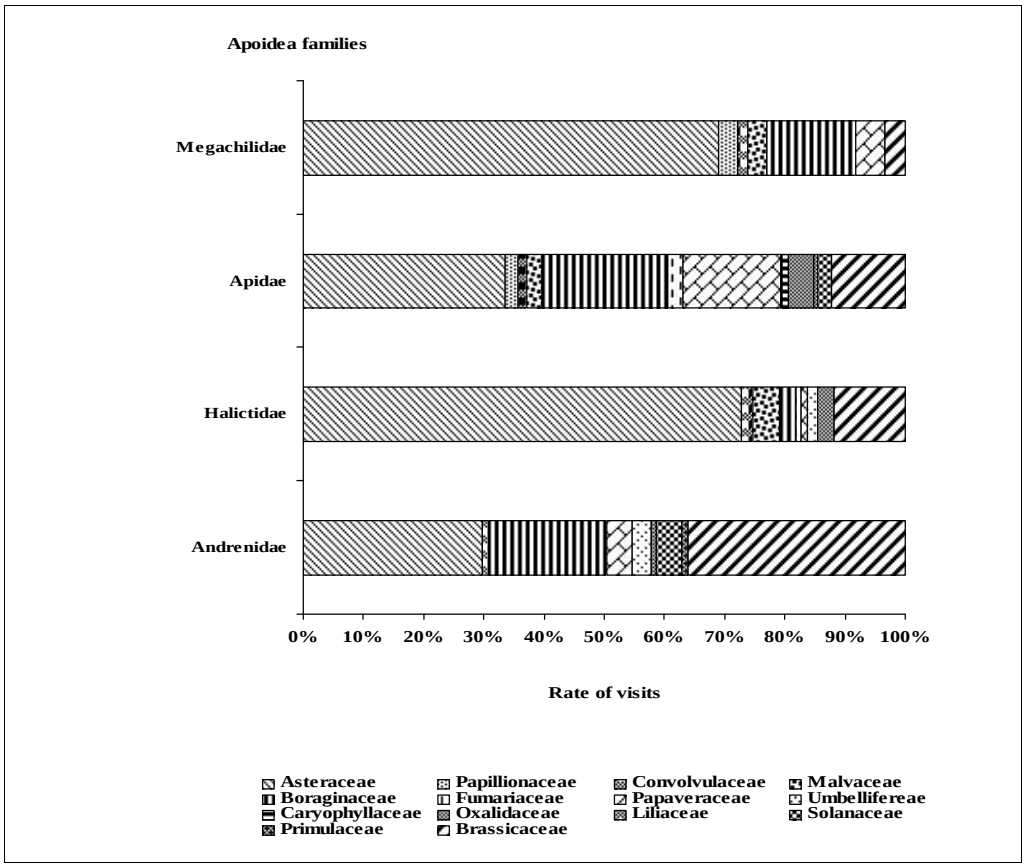

Fig.1. Distribution of flower visits by families of Apoidea between the main plant families for 2003 and 2004

Table 2. Distribution of floral visits by the main bee families.

	Principal families of Apoidea				Total
	Apidae	**Halictidae**	**Andrenidae**	**Megachilidae**	**number**
Number ofvisits	352	110	97	61	620
% of visits	56.8	17.7	15.6	9.8	100
Number of speciesvisiting	28	28	28	24	108
Number of plant families visited	13	9	10	5	15
Number of plant species visited	26	16	21	12	36

In this study, we determined the floral choices shown by wild and domesticated bees, and we give an estimate of their food specialization in their natural habitats during spring and the end of winter.

Every bee species had its own preference. Bees have generally more nectar sources than pollen hosts [39]. Some plants attract bees more than others, possibly due to the nectar composition, according to the plant family or life form (geophyte, herbaceous perennial, woody perennial, therophyte) and flower morphology [35]. The attractiveness of any given species is a function of variables such as colour, nectar volume, sugar concentration and fragrance [40] and the bees fly to plant species that yield the greatest nectar and pollen amounts [41]. [42] observed that buckwheat growing in the vicinity of red clover distracted bees from pollination of the red clover. The results obtained in this study revealed that among the plant families visited, three of them accounted for almost 2/3 of all the visitations. On the basis of the number of bee species identified, the Brassicaceae were the most important plant families, followed by Asteraceae and Boraginaceae. [35] noted that Asteraceaeare visited by 60% of identified species of bees. It seems that the Asteraceae and Brassicaceaeare very much appreciated by bees.

Among the plants sought by bees in our study, the most visited one was *Anchusa azurea;* it concentrated 15.2% of the total number of visits. It was followed by *Galactites tomentosa* (12.1%), *Papaver rhoeas* (9.2%), *Centaurea pullata* (8.7 %) and *Sinapis arvensis* (8.6%). The plant with the highest number of visits by bees (34) was *Sinapis* arvensis, the majority of them belonging to Halictidae and Andrenidae (short-tongued). This explains, at least in part, the

specificity of bees for a specific plant. *Anchusa azurea* attracted high numbers of long-tongued bees in the sub-family Anthophorinae (4 species) [43,44], a group characterised by very rapid foraging [45].This choice may be related to the composition of its nectar, rich in sucrose and amino acids, found in a tube formed by fused petals [46,47]. More Anthophorinae species are very active in the spring on this same plant species [48].

Bees certainly like the Brassicaceae [49], reported that the members of this family were preferred by Andrenidae, followed by Apidae, Halictidae and Megachilidae. The most appreciated plant family by Apidae, Halictidae and Megachilidae was the Asteraceae because its flowers are easily accessible for these bees. The length of the floral tube usually determines the bee's access to nectar [50,51]. As for the Andrenidae, they seem to prefer the Brassicaceae, because they can easily access the nectar in these open-access flowers with their short tongues.

Table 3 shows that among the 15 species of Apoidea studied, the majority of species of solitary bees are oligolectic. The highest Isf concerns *Halictus scabiosae* with a value equal to 1; it was followed by *Halictus rufipes*, *Osmia pinguis* and *Osmia tricornis*, with Isf = 0.96. They were followed by *Osmia caerulescens* with Isf = 0.9. These species are oligolectic because they concentrated their visits on a single plant family, the Asteraceae for both *Halictus* species and *Osmia pinguis* and the Boraginaceae for *Osmia tricornis.* Amongst the other bee taxa, there was a preference for Asteraceae. The other bees whose Isf is below 0.4 are polylectic, with the lowest index belonging to *Apis mellifera* (0.16; (Table 3)). In fact, this species visited all the plant families except for two (Ranunculaceae and Caryophyllaceae). When we consider the plant species indices (Isp; Table 3), the majority of bees with a high Isf also have a high Isp, thus confirming their oligolecty. *Eucera eucnemidea* presented the lowest Isp (0.2), which demonstrates that it is more eclectic in its floral visits.

The Isf/Isp value for *Halictus scabiosae* was the highest (2.1; Table 3), and this indicates clearly that this species concentrated its visits only on plants of a single family (Asteraceae). On the other hand, *Eucera notata* showed the lowest Isf/Isp value. This reflects a broad preference towards both species and plant families visited.

The food niche is expressed by the Shannon Diversity Index (H').H'fis calculated for families and H'p for plant species. *Halictus rufipes, Halictus scabiosae, Osmia pinguis* and *Osmia*

tricornis presented H'f values in the 0.01 - 0.06 bits interval (Table 3). *Apis mellifera* had the broadest value (2.97 bits), followed by *Bombus terrestris* (2.11 bits) and *Eucera eucnemidea* (2.01 bits).

At the species level, *Apis mellifera, Andrena flavipes, Anthophora atriceps, Eucera eucnemidea* and *Bombus terrestris* each have a high H'p value; this means that they visited a broad spectrum of plant species belonging to several families as forage sources, reflecting a polylectic behaviour (Table 3). Conversely, those with H'p< 1 prefer one or two plants belonging to a single family. This is the case of *Halictusrufipes* (H'p = 0.01), *Osmia tricornis* (H'p = 0.05), *Osmia pinguis* (H'p = 0.06), *Osmia caerulescens* (H'p = 0.59) and *Eucera notata* (H'p = 0.73). Species whose H'p is equal, or close to 1 were *Andrena ferrugineicrus*, *Megachile rotundata* and *Halictus scabiosae*. They concentrated their visits only on one or a few plant species.

Table 3. Simpson Flower Visitation Index (Isp, Isf) and Shannon Diversity Index (H'p, H'f) of the food niche for the most abundant bee species.

Species	Rate of visits	Isp	Isf	Isf/Isp	H'p	H'f	Number of plants visited
Andrena ferrugineicrus Dours, 1872	11	0.42	0.47	1.12	1.00	1.16	5
Andrena flavipes Panzer, 1799	42	0.25	0.38	1.52	2.07	1.77	9
Panurgus sp.	11	0.32	0.5	1.56	1.41	1.13	6
Halictus rufipes (Fabricius, 1793)	8	0.97	0.96	1.00	0.01	0.02	1
Halictus scabiosae (Rossi, 1790)	16	0.47	1.00	2.12	0.99	0.03	
Lasioglossum discum (Smith, 1853)	7	0.33	0.6	1.82	1.38	0.71	4
Osmia caerulescens Linnaeus, 1758	21	0.74	0.90	1.21	0.59	0.25	
Osmia pinguis Pérez, 1895	11	0.97	0.96	1.00	0.06	0.04	
Osmia tricornis Linnaeus, 1811	4	0.97	0.96	1.00	0.05	0.04	
Megachile rotundata (Fabricius,	12	0.56	0.40	0.71	1.03	1.37	7

1793)							
Anthophora atriceps Pérez, 1879	31	0.25	0.33	1.32	2.06	1.65	
Eucera notate Lepeletier, 1841	19	0.65	0.33	0.51	0.73	1.79	7
Eucera eucnemidea Dours, 1873	13	0.21	0.23	1.09	2.04	2.01	9
Apis mellifera Linnaeus, 1758.	214	0.27	0.16	0.59	2.9	2.97	
Bombus terrestris (Linnaeus, 1758)	17	0.23	0.21	0.91	1.89	2.11	

The concentration of wild honey bees and solitary bees also indicates the degree of food specialization. We note in Table 3 that only a species had an Isf value equal to 1: it is *Halictus scabiosae*. In *Halictus rufipes*, *Osmia caerulescens*, *Osmia tricornis*, *Osmia pinguis*, and *Osmia tricornis*, Isf was ≥ 0.9. These species are oligolectic because they concentrate their visits on a single plant family. For *Osmia tricornis*, the preferred family was Boraginaceae; on the contrary, other bees chose Asteraceae. Bees whose Isf is under 0.4 are polylectic, such as *Andrena flavipes, Anthophora atriceps* or *Eucera notate* (0.33). *Bombus terrestris* (0.21) and *Apis mellifera* (0.16) had the lowest values. [36] stressed that oligolectic and polylectic species coexist in all the inventories of bee faunas; however, the proportions seem to be very clear. The highest percentages of oligolectic bee species are observed in the desert and in Mediterranean climates. The Apidae *Eucera eucnemidea* had the lowest Isp (0.21). This species seems to be eclectic in its floral visits [35]. *Halictus scabiosae* had the highest Isf / Isp ratio; it concentrated its visits to many plant species belonging to its favourite family (Asteraceae).

The width of the food niche is the Shannon-Weaver diversity index (H') [35,37]. H'fis calculated for families and H'p for plant species. *Halictus rufipes, Halictus scabiosae, Osmia pinguis* and *Osmia tricornis* had the lowest H'f values (and close to 0.01). On the other hand, *Apis mellifera* showed the widest niche, followed by *Bombus terrestris* and *Eucera eucnemidea*. [37] reported in a study on the competition between solitary and honey bees towards floral resources, an H' equal to 3.1 bits. This is because both groups use intensely flowers [37]. Concerning *Bombus terrestris*, this species is polylectic. Several authors [52, 53, 37, 54] recognised that bumblebees are extremely polylectic. About solitary bees, they are oligolectic [49]; as they are affected by the presence of *Apis mellifera*, they cannot compete. This is due to

their specialisation for certain plant species [55,37,56]. Then, they adapt to the plant that serves as a source of pollen recognition by the plant [57], adaptation to the crop [36] and the timing of phenology. According to [58], the timing of phenology between the insect and the plant is very important.

3. EXPERIMENTAL

3.1. Study site

The study was carried out in a 3.5 hectare plot of land within the experimental part of the park of the High School of Agronomy of El Harrach (Algiers) (36º 43’ N,3º 8’ E; altitude:50 m), situated in the eastern part of the Algerian littoral (Figure 2). The average temperature during the study period was 13.6°C in 2003 and 12.6°C in 2004. The rainfall was 640 mm in 2003 and 706.3 mm in 2004. The total duration of sunshine was 2,965 hours in 2003 and 2,718 in 2004 (data from the meteorological station at Dar El Beida).

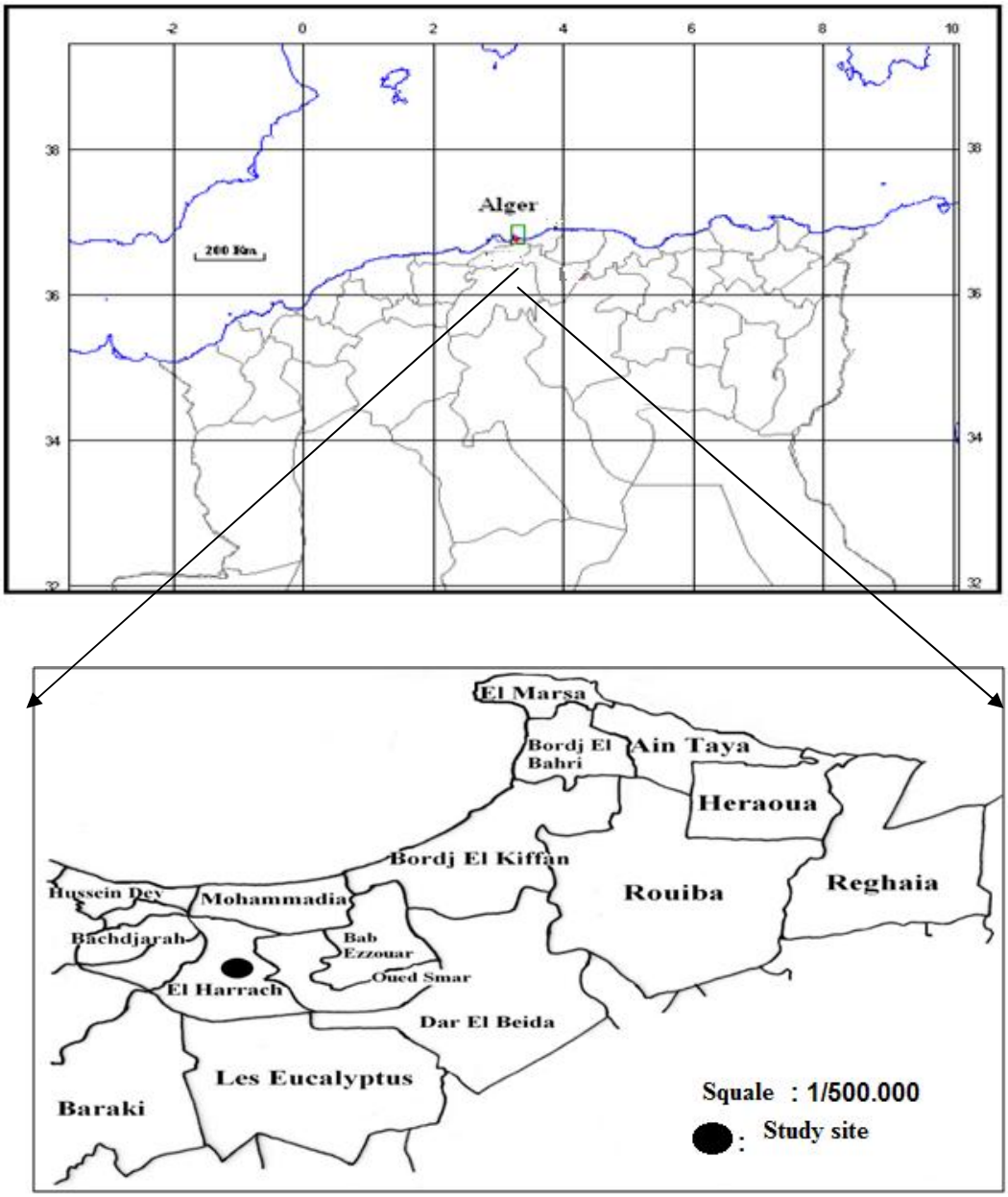

Fig.2. Geographycal situation of prospected site

3.2. Flora

The study site is an open environment dominated by therophytes, with a clay-silt soil type. To determine the flowering time of wild plants and monitor their development, floral observations began in January and continued until the end of June both in 2003 and 2004. Samples of the plants visited by bees were collected and deposited in the herbarium in order to be dried and storaged, and were subsequently determined following [59].

3.3. Bees

Flower visiting bees were sampled once a week between 08:00 and 12:00 (GMT + 1) from 1 February to 25 June 2003 and 2004. Several sampling methods were employed to collect the maximum number of species. To capture large bees (such as Xylocopini, Anthophorini and Bombini) we used a sweep net [60,61]. This method was used in vegetation not exceeding 0.5 m in height.

Net traps and coloured pan traps were used when weather conditions were favourable to bee foraging: when the maximum daily temperature was at least 15 ° C, there was little wind (<20-25 km / h) and no precipitation, and the vegetation was dry [62]. The captured bees, preserved in 70% ethanol, were then dried, assembled and prepared in order to allow their identification. Insect nets were used as well; the specimens were killed using ethyl acetate and preserved in vials until their definitive mounting at the laboratory.

3.4. Statistics

Flower visits by bees were quantified with the Simpson Concentration Index (Is) [63]. (Simpson, 1949). For a given taxon, the foraging rate or visitation observed to a particular botanical family or species is the percentage of individuals of this taxon visiting the family or species, calculated in relation to all floral visits by this taxon:

$$Is = \sum_{i=1}^{q} \frac{ni(ni-1)}{N(N-1)}$$

where: ni = number of visits observed on the study plant; N = total number of visits observed on all plants, Is values vary between 0 and 1. The index is used to evaluate food specialization.

The food niche was evaluated with the Shannon Diversity Index (H') [35, 27, 29]:

$$H' = -\sum_{i=1}^{ni} pi \log 2\, pi$$

where pi = ni / N, the proportion of visits to the *n th* plant.

H' will increase proportionally to the number of plants visited and the balanced use of the different plants by the individuals of a given bee species.

Food specialization of bees was examined in two respects: degree of food specialization and food niche. The degree of food specialization was calculated with the Simpson Floral

Visitation Index [63] (Isf, Isp). Isf is used for plant families and Isp for species. The indices vary from 0 to 1. The values of these indices are reported in Table 3. The Isf and Isp indices were calculated only for the main bee species.

4. CONCLUSION

The bee fauna in the Algiers region presented distinctive preference for certain flowers and this was related to the nature of the native plants found in that particular area.

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Table 1. Total number, rate of floral visits and number of bee species visiting flowering melittophilous plant species.

Plant species visited	**Plant families**	**Total number of visits**	**Rate of Floral visits (%)**	**Number of species visiting**
Anacyclus clavatus (Desf.) Persoon	Asteraceae	28	4.1	12
Andryala integrifolia Linnaeus	Asteraceae	38	5.6	5
*Centaurea pullata*Linnaeus	Asteraceae	59	8.7	21
*Galactites tomentosa*Moench	Asteraceae	82	12.1	26
Chrysanthemum paludosum Poiret	Asteraceae	11	1.6	8
Cichorium intybus Linnaeus	Asteraceae	5	0.7	3
Crepisve sicaria Linnaeus	Asteraceae	18	2.7	9
Picris echioides Linnaeus	Asteraceae	14	2.1	27
Scolymus hispanicus Linnaeus	Asteraceae	38	5.6	7
Sonchus asper (L.) Hill	Asteraceae	6	0.9	6
Anchusa azurea Miller	Boraginaceae	103	15.2	20
Borago officinalis Linnaeus	Boraginaceae	1	0.1	1
Raphanus raphanistrum Linnaeus	Brassicaceae	30	4.4	15
Sinapis arvensis Linnaeus	Brassicaceae	58	8.6	34
Stellaria media Linnaeus	Caryophylaceae	2	0.3	1

Convolvulus althaeoides Linnaeus	Convolvulaceae	6	0.9	4
Convolvulus arvensis Linnaeus	Convolvulaceae	2	0.3	1
Convolvulus tricolor Linnaeus	Convolvulaceae	3	0.4	2
Hedysarum coronarium Linnaeus	Fabaceae	3	0.4	1
Hedysarum flexuosum Linnaeus	Fabaceae	1	0.1	1
Lupinus angustifolius Linnaeus	Fabaceae	3	0.4	2
Medicago sativa Linnaeus	Fabaceae	6	0.9	5
Viciasicula (Raf.) Guss.	Fabaceae	16	2.4	7
Fumaria agrarian Lag.	Fumariaceae	6	0.9	1
Fumaria capreolata Linnaeus	Fumariaceae	1	0.1	1
Asphodelus microcarpus Salzm. & Viv.	Liliaceae	2	0.3	1
Lavatera cretica Linnaeus	Malvaceae	3	0.4	1
Lavatera trimestris Linnaeus	Malvaceae	3	0.4	2
Malva sylvestris Linnaeus	Malvaceae	12	1.8	1
Oxalis pes-caprae Linnaeus	Oxalidaceae	24	3.5	13
Papaver rhoeas Linnaeus	Papaveraceae	62	9.2	9
Anagallis arvensis Linnaeus	Primulaceae	3	0.4	3
Ranunculus macrophyllus Desf.	Ranunculaceae	2	0.3	2
Salpichroa origanifolia (Lam.) Baill.	Solanaceae	16	2.4	2
Daucus carota Linnaeus	Umbellifereae	2	0.3	2
Torilis arvensis (Huds.) Link	Umbellifereae	5	0.7	2
Total		**677**	**100**	**108**

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