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Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/sgra20>

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Available online: 18 Feb 2011

To cite this article: Alicia Forcone, Pía Valeria Aloisi, Silvina Ruppel & Miriam Muñoz (2011): Botanical composition and protein content of pollen collected by *Apis mellifera* L. in the north-west of Santa Cruz (Argentinean Patagonia), *Grana*, 50:1, 30-39

To link to this article: <http://dx.doi.org/10.1080/00173134.2011.552191>

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Botanical composition and protein content of pollen collected by *Apis mellifera* L. in the north-west of Santa Cruz (Argentinean Patagonia)

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Abstract

This paper reports the pollen sources selected by *Apis mellifera* in the area northwest of Santa Cruz (Argentina). It evaluates the relative biomass contribution and the protein content of the collected taxa. During the apicultural period (September 2008–March 2009) pollen loads from three colonies were collected every fortnight using pollen traps. Forty-two pollen types were found in the samples, from which 15 taxa had a biomass contribution over 1% of the total pollen crop. The main pollen sources were Brassicaceae, *Taraxacum officinale*, *Convolvulus arvensis*, Rosaceae, *Salix* spp. and *Schinus marchandii* (Anacardiaceae). Of the total pollen sources identified, 15 are new records for the bee pollen flora of Argentina and 13 are native plants of South America. The contribution of native flora occurred mainly in spring. *Schinus marchandii*, *Mulguraea-Junellia* type (Verbenaceae), *Adesmia* spp. (Fabaceae), *Sysirinchium* spp. (Iridaceae), *Acaena* spp. (Rosaceae), Astereae and *Senecio* spp. (Asteraceae) were the indigenous pollen types with the highest biomass contribution. Protein content of most collected pollen types was variable (between 13.25% and 24.43%).

Keywords: Pollen loads, pollen sources, Patagonia, bee-plants, honey bees, Argentina

Pollen is the essential food for the growth and development of honey bees. It is the most important source of proteins and also supplies vitamins, minerals, free amino acids and lipids. Pollen is necessary for the development of larvae and the longevity of the colony (Schmidt et al., 1987; Louveaux, 1990; Roulston & Cane, 2000).

Apis mellifera L. transports pollen to the hives in specialised structures of its legs (corbicula), in which pollen, moistened with nectar and saliva, is packaged forming pasty ‘pellets’, called ‘pollen loads’ (Thorp, 2000). These loads are generally monospecific due to the high grade of floral constancy of *A. mellifera*. A pellet’s colour and morphology depend on the botanical source or origin (Free, 1963; Louveaux, 1990). Knowledge of pollen loads composition and their protein contents are valuable tools for apicultural development. Analysis of pollen loads throughout the foraging season enables a

determination of the pollen flora that bees select in a region, and allows evaluation of the annual contribution by each plant taxon (Louveaux, 1990).

The protein contents from pollen loads (usually estimated from nitrogen levels) provides information on nutritional quality of resources harvested by bees. Pollen with less than 20% crude protein cannot satisfy colony requirements for its development and optimum production (Shaw, 1999). A range from 23 to 30% is the optimum for bees to successfully rear brood (Herbert et al., 1977).

In Argentina, there are only a few studies on the botanical composition of pollen loads and pollen flora and most are from the central region of Argentina, where apiculture is more developed (Tellería, 1993; Basilio, 2000; Forcone, 2002; Andrada & Tellería, 2005; Naab & Tamame, 2007). Today, the unfavourable impact of extensive soybean crops in the central region of Argentina on honey

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(Received 16 July 2010; accepted 20 December 2010)

ISSN 0017-3134 print / ISSN 1651-2049 online © 2011 Collegium Palynologicum Scandinavicum
DOI: 10.1080/00173134.2011.552191

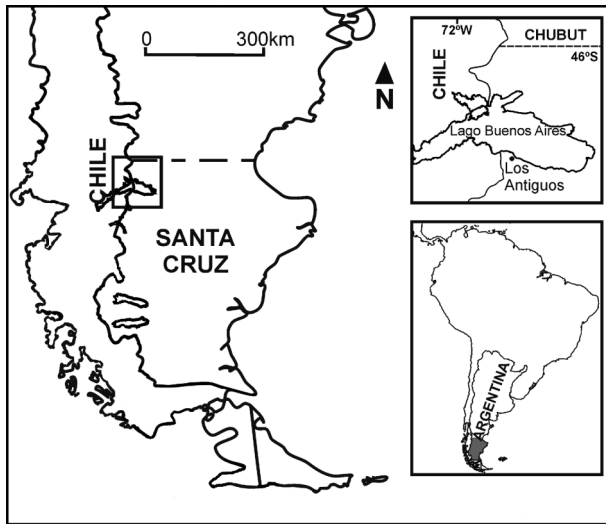


Figure 1. Geographical location of the study area.

bees and the growing demand for contaminant-free honey products has raised beekeepers' interest in the melliferous areas of Patagonia. In this region, human impact is low and diversity of native vegetation offers possibilities for development of beehives and diversification of production. Even though the apiculture industry has grown in recent years, it is still at an early stage, being practised in irrigated valleys and in the Andean humid region.

The Santa Cruz Province (Figure 1), located in the southern part of Argentina, is the largest province in the Argentinean Patagonia. The climate in most of this area is arid, with low temperatures almost year-round and strong winds from the west. The climatic conditions limit apiculture, which is poorly developed in this province. The Lago Buenos Aires Basin in the northwest of the province is the only area where apiaries are permanently established; most of them are concentrated in the Los Antiguos valley (Figure 1).

This research is part of an integrated project that aims to understand the botanical resources of Patagonia that can be used in apiculture. Most melissopalynological research in Patagonia characterises nectariferous flora and honeys palynologically (Forcone & Tellería, 1998, 2000; Tellería & Forcone, 2000; Forcone, 2008; Forcone et al., 2003, 2005, 2009). To date, there has only been one study on pollen flora of the Lower Valley of Chubut River (Forcone, 2002). The aim of the present research is to identify the pollen sources that support the hives in the north-western part of the Santa Cruz Province and to evaluate the contribution of each taxon in terms of biomass and protein content. Previous studies in this area record the nectar sources (Forcone et al., 2009) and flowering period of plants visited by honey bees (Forcone & Muñoz, 2009).

Materials and methods

Study area

In Los Antiguos valley ($46^{\circ} 33' S$ and $71^{\circ} 38' W$), one apiary was selected. The valley has a temperate-semiarid climate with a mean annual temperature of $8.9^{\circ} C$ and an average annual precipitation of 192 mm. The average wind speed is 5.3 km/h; the windiest period is during August to October (González & Rial, 2004; San Martino & Manavella, 2004). Vegetation is comprised in a transitional region between the Patagonian phytogeographical province and the grassy steppes of the Subantarctic Province (Roig, 1998). Different physiognomic types of vegetation alternate: shrubby steppe, brushwood and herbaceous steppe. The most common taxa include *Adesmia boronioides* Hook.f., *Adesmia volckmannii* Phil., *Acaena* spp., *Berberis microphylla* G. Forst., *Baccharis* spp., *Colliguaja integerrima* Gill et Hook., *Mulguraea ligustrina* (Lag.) N. O'Leary et P. Peralta, *Mulinum spinosum* Pers., *Schinus marchandii* F. A. Barkley, *Senecio patagonicus* Hook et Arn., *Sisyrichium* spp. and Poaceae.

Agriculture activity is based on irrigation. Most of the cultivated area is planted with cherry trees (*Prunus avium* L.). Fodder crops, mainly alfalfa (*Medicago sativa* L.) follow cherry trees in order of importance. Other fruit is also cultivated, including *Malus sylvestris* (L.) Mill., *Pyrus communis* L., *Prunus persica* (L.) Batsch., *Rubus idaeus* L., *Ribes* spp. and *Fragaria* $\times$ *annanasa* Duch. Horticultural plants are cultivated to a lesser degree. *Populus nigra* L. prevails among forest species. In croplands and along irrigation channels weeds grow such as *Convolvulus arvensis* L., *Taraxacum officinale* G. Weber ex F. H. Wigg and *Brassica* spp. Apiculture is complementary to agriculture as bees are used for the pollination of fruit crops.

Sampling from corbicular pollen

Samples were obtained from pollen traps with 10% efficacy (Louveaux, 1968) placed in three randomly chosen beehives in the apiary. The traps were in place every 15 days for one complete day (cf. García-García et al., 2004) throughout the apicultural period from 13 September 2008 to 16 March 2009. Sampling frequency varied in December due to adverse climatic conditions. Three grams of each pollen load per trap were examined in order to identify pollen types. Pollen loads collected during each day of sampling from the three chosen hives were considered as one sample, 11 samples were taken in this way from the apiary.

At the same time as pollen load sampling, vegetation within a radius of 1.5 km around the hive was

surveyed. All vascular plants species were recorded except Poaceae, due to the low apicultural value of the latter (Louveau, 1985). Herbarium specimens were made of every species and deposited in the Herbario Trelew (HTW), Facultad de Ciencias Naturales, Universidad Nacional de la Patagonia, San Juan Bosco (Sede Trelew).

Pollen loads analysis

Samples were stored frozen until analysis. Pollen loads were firstly sorted by colour (macroscopically); loads of the same colour were classified according to morphology (shape and texture) using a stereoscopic microscope. Pollen of at least three loads of each classified type was mounted on slides in two ways: fresh and acetolysed (cf. Erdtman, 1960). Identification was made by comparison with a pollen reference collection made from the plants of the study area. The taxonomic identification was done at the lowest level possible. The Pollen reference collection was donated to the Palynothèque of the Facultad de Ciencias Naturales, Universidad Nacional de la Patagonia, San Juan Bosco (Sede Trelew).

To determine the relative importance of the different plants in the honey bees' diet, pollen loads from each taxon were dried in an oven at 48 °C for 48 hours and then weighed (cf. Montenegro et al., 1992). The percentage contribution to biomass of each taxon was calculated in every sample and in the total samples collected during the study period. For nitrogen content determination, 50 mg of each pollen type (cf. AOAC, 1980) was analysed by the micro-Kjeldahl methods (cf. Bremner & Mulvaney, 1982), and crude protein was estimated using the factor 6.25 (cf. Roulston & Cane, 2000). Samples weighing less than 50 mg were excluded. Nitrogen content analysis was made in LANAIS N 15 (National Laboratory of Research and Services UNS-CONICET), Department of Agronomy, Universidad Nacional del Sur, Bahía Blanca, Argentina.

Results

Collected pollen

A total of 316.2 g of corbicular pollen was collected in the traps during the sampling period (Table I). Values obtained in each sampling ranged from 16.6 to 48.9 g, with peaks during October and February. Daily collection per colony varied on average between 5.5 and 16.3 g (Table I). According to the model of trap utilised (10% efficacy), the estimated value of collection per colony/day ranged between 55 and 163 g (Table I).

Table I. Fresh weight of pollen collected with traps during the apicultural period September 2008–March 2009 in the area north-west of Santa Cruz (Argentina).

Sampling data	Fresh weight collected (g)	Mean fresh weight colony/ day (g)	<i>E</i>
13 September	34.4	11.46	114.60
6 October	33.6	11.20	112.00
21 October	28.1	9.36	93.60
10 November	30.0	10.00	100.00
28 November	18.2	6.03	60.30
17 December	21.2	7.06	70.60
8 January	16.6	5.53	55.30
21 January	26.0	8.66	86.60
7 February	37.8	12.60	126.00
23 February	48.9	16.30	163.00
16 March	21.4	7.13	71.30
Total	316.2	105.40	1054.00

Mean fresh weight by colony/day: obtained values and estimated (*E*) values (according to the traps utilised with an efficacy of 10%).

Pollen sources and biomass contribution

The survey of the vegetation surrounding the hives documented 140 species of vascular plants (excl. Poaceae), belonging to 41 families. Asteraceae were most common with 26 species; Fabaceae and Rosaceae followed the Asteraceae in the number of species, both with 15 species each.

Of the total recorded taxa only 42 were found in the samples (Table II). Thirty-four pollen types came from insect-pollinated plants and eight from wind-pollinated plants. Eighteen types were identified to species rank, 19 to a generic rank, three to tribe and two to family level. All the taxa determined in the collected pollen came from plants found within a radius of 1.5 km of the apiary. Families with greatest diversity of pollen types were Asteraceae and Fabaceae. The number of sources of pollen used by *Apis mellifera* showed limited variation throughout the study period. A maximum diversity was observed in the first half of November, when 14 pollen types were recorded (Table II).

Only 0.9% of the total biomass obtained were mixed pollen loads; the remaining were homogeneous loads from one of the 42 sources identified. Fifteen of these homogeneous loads contributed to more than 1% of the biomass obtained during the apicultural period. Brassicaceae made the greatest contribution with 42.2% of the total biomass collected (extrapolated from Table II). Five sources contributed between 3% and 9% including *Taraxacum officinale* (Asteraceae), *Convolvulus arvensis* (Convolvulaceae), Rosaceae, *Salix* spp. (Salicaceae) and *Schinus molle* (Anacardiaceae). Nine taxa contributed between 1% and 3% including *Astereae* and *Senecio* spp.

Table II. Pollen types collected by *Apis mellifera* in the area northwest of Santa Cruz (Argentina).

Family and pollen type	Growth-form	Samples (mg)										Total (mg)	Percentage
		13 Sept.	6 Oct.	21 Oct.	10 Nov.	28 Nov.	17 Dec.	8 Jan.	21 Jan.	7 Feb.	23 Feb.	16 Mar.	
ANACARDIACEAE													
<i>Schinus molle</i> ***	S			2874	1493							4367	4.67
APIACEAE													
<i>Mulinum spinosum</i> *	S						10					10	0.01
ASTERACEAE													
<i>Arenaria</i> sp. (a)	S					253		15	31	45	15	36	0.03
Asteraceae*	S, H				901				429	11		1694	1.81
<i>Xanthium</i> sp.	H									66		74	0.01
Anthemideae	H				8				34	220	2	24	0.08
<i>Carduus</i> spp.	H						9	27		20		314	0.34
<i>Cichorium intybus</i>	H									20		20	0.02
Cichorieae	H										25	25	0.03
<i>Cirsium vulgare</i>	H							5	22	82		108	0.12
<i>Leucheria achillaeifolia</i> *	H					348						348	0.37
<i>Senecio</i> spp.*	S				54	2317	253					2624	2.81
<i>Taraxacum officinale</i>	H	1	759	4602	773	618	4	88	25	1158	36	566	9.23
BERBERIDACEAE													
<i>Berberis microphylla</i> *	S	49	26									75	0.08
BRASSICACEAE													
Brassicaceae	H	3	45	191	2059	3384	6362	4503	5432	3769	6835	39449	42.20
CARYOPHYLLACEAE													
<i>Cerastium arvense</i>	H			5								5	0.01
CHENOPODIACEAE													
Chenopodiaceae (a)	H, S.				40						5	45	0.05
CONVOLVULACEAE													
<i>Convolvulus arvensis</i>	H					58	668	2581	1821	627	223	47	6.44
CUPRESSACEAE													
<i>Cupressus</i> spp. (a)	T	315										315	0.34
EPHEDRACEAE													
<i>Ephedra ochroleuca</i> *	S						7					7	0.01
EUPHORBIACEAE													
<i>Colliguaja integrifolia</i> *	S			363								363	0.39
FABACEAE													
<i>Adesmia</i> spp.*	S				836	507						1343	1.44
<i>Trifolium</i> spp.	H						12		313		10	335	0.36
<i>Trifolium pratense</i>	H						165					165	0.18
<i>Medicago sativa</i>	H							700		12		824	0.88
<i>Melilotus</i> spp.	H						12	61	85	356	54	579	0.62

(Continued)

Table II. (continued).

Family and pollen type	Growth-form	Samples (mg)										Total (mg)	Percentage
		13 Sept.	6 Oct.	21 Oct.	10 Nov.	28 Nov.	17 Dec.	8 Jan.	21 Jan.	7 Feb.	23 Feb.	16 Mar.	
GERANIACEAE													
<i>Erodium cicutarium</i>	H	46	27	28	173	145		17	3	29	3	332	801 0.86
HYDROPHYLLACEAE	H												
<i>Phacelia secunda</i> *	H				30								30 0.03
IRIDACEAE	H												
<i>Sisyrinchium</i> spp.*	H	3	990										993 1.06
MALVACEAE	H												
<i>Malva</i> sp.	H							3					3 0.00
ONAGRACEAE	H												
<i>Oenothera</i> spp.*	H					21		513		215			748 0.80
PINACEAE													
<i>Pinus</i> spp. (a)	T	154			14								168 0.18
PLANTAGINACEAE													
<i>Plantago</i> spp. (a)	H					310	58	148	287	916	115		1833 1.96
ROSACEAE													
Rosaceae	T, S	99	5248	47									5394 5.77
<i>Acaena</i> spp.*	H					389	751		70				1210 1.29
SALICACEAE													
Salix spp.	T	4052	1157										5209 5.57
<i>Populus</i> spp. (a)	T	2337											2337 2.50
TYPHACEAE													
<i>Typha subulata</i> * (a)	H											806	806 0.86
TROPAEOLACEAE													
<i>Tropaeolum porifolium</i> *	H				40								40 0.04
ULMACEAE													
<i>Ulmus</i> spp. (a)	T	1475											1475 1.58
VALERIANACEAE													
<i>Valeriana clarionifolia</i> *	H			111									111 0.12
VERBENACEAE													
<i>Mulgunaea-funellia</i> type*	S		148	141	1759	12							1912 2.05
Mixed loads				30	9	170	142	128	70	57	74	21	849 0.91
Unidentified pollen					10								10 0.01
Fungal spores										1129	644		1773 1.90
Total classified pollen loads (mg)		8534	8400	8392	8199	8532	8453	8787	8623	8709	8009	8851	93489 100

Biomass contribution in milligrams (September 2008–March 2009). Bold typeface: pollen types with greater biomass contribution; *native plants; (a) wind-pollinated plants; H, herb; S, shrub; T, tree.

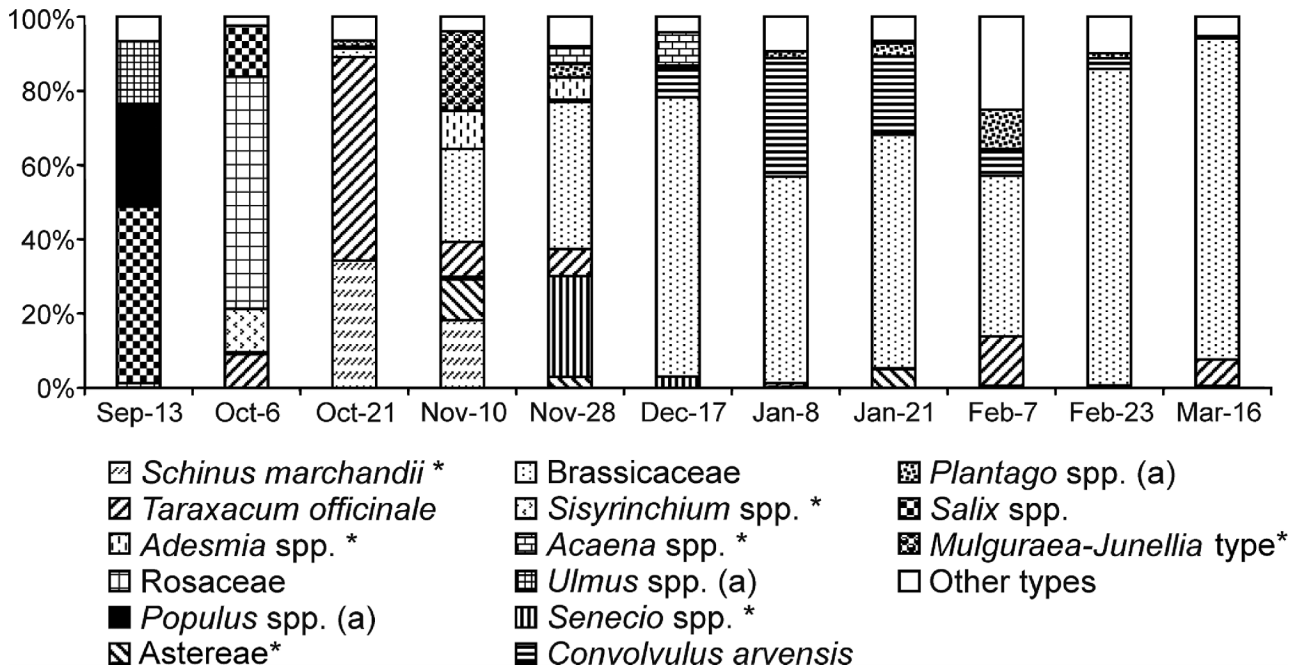


Figure 2. Main sources of pollen in the area northwest of Santa Cruz (Argentina). Biomass contribution during apicultural period 2008–2009; *native plants; (a) wind-pollinated plants.

(Asteraceae), *Adesmia* spp. (Fabaceae), *Sysirinchium* spp. (Iridaceae), *Plantago* spp. (Plantaginaceae), *Acaena* spp. (Rosaceae), *Populus* spp. (Salicaceae), *Ulmus* spp. (Ulmaceae) and *Mulguraea-Junellia* type (Verbenaceae). The remaining taxa contributed with less than 1% of the total biomass collected (Table II).

Towards the end of the winter, Salicaceae dominated the collected pollen with *Salix* spp. and *Populus* spp. as the main sources. At the beginning of spring, Rosaceae prevailed in the samples (Figure 2). This pollen type came from fruit trees (mainly *Prunus* spp.) and ornamental plants (*Rosa* spp., *Crataegus* spp.).

During mid-spring (second half of October and November), the contribution of Asteraceae was marked. *Taraxacum officinale* was the most collected type, followed by native species of *Senecio* (mainly *Senecio patagonicus*) and Astereae. The latter was represented in the area by *Nardophyllum bryoides* (Lam.) Cabrera, *Baccharis darwinii* Hook et Arn., *B. juncea* (Cass.) Desf. and *B. patagonica* Hook et Arn. At this time of the year, a high contribution in biomass from *Schinus marchandii* was also recorded.

Brassicaceae increased gradually in the flow of pollen to the hives. At the end of spring and during summer, the highest contribution of pollen to the hives came from weeds associated with crops, mainly Brassicaceae and *Convolvulus arvensis*. Genera from Brassicaceae cannot be distinguished from each other due to palynological similarities. Species found in the

area were: *Brassica nigra* (L.) W. D. J. Koch, *Brassica rapa* L., *Eruca vesicaria* (L.) Cav., *Erysimum repandum* L., *Mostacillastrum commune* (Speg.) Al-Shehbaz and *Lepidium draba* L.

Pollen from wind-pollinated plants was collected mainly at the end of winter and came from forest species including *Populus* spp., *Ulmus* spp., *Cupressus* spp. and *Pinus* spp. Anemophilous pollen was observed in a scarce proportion towards the end of spring and during summer. In the latter season, the main source was *Plantago* spp.; other sources included Chenopodiaceae, *Typha subulata* Crespo et R. L. Perez-Mor and *Artemisia* sp. (Figure 2, Table II).

Introduced species were prevalent in all samples, except during November, when native plants contributed 48% and 63% of the biomass (Figure 3). The most collected native pollen-types were: *Schinus marchandii*, *Adesmia* spp., Astereae, *Senecio* spp., *Acaena* spp., *Sysirinchium* spp. and *Mulguraea-Junellia* type. The latter was represented in the area mainly by *Mulguraea ligustrina*.

Woody plants were the main pollen source at the end of winter and early spring (September–October). Towards the end of spring and during the summer, the flow of pollen to the hives came mostly from herbaceous plants (Figure 4). During sampling in February, pollen loads from fungal spores were also observed. Biomass contribution varied between 1129 mg (13%) and 644 mg (8%) for the first and second fortnight, respectively (Table II).

Table III. Nitrogen and protein content of pollen collected by honey bees in the area northwest of Santa Cruz (Argentina).

Taxa	Nitrogen content (%)	Crude protein (%)
<i>Acaena</i> spp.	2.68	16.75
<i>Adesmia</i> spp.*	4.22	26.30
Asteraceae*	2.45	15.31
<i>Berberis microphylla</i> *	2.68	16.75
Brassicaceae	3.40	21.25
<i>Carduus</i> spp.	2.97	18.56
<i>Cirsium vulgare</i>	3.04	19.00
<i>Colliguaja integerrima</i> *	2.81	17.50
<i>Convolvulus arvensis</i>	3.22	20.12
<i>Cupressus</i> spp. (a)	1.05	6.56
<i>Erodium cicutarium</i>	1.98	12.37
<i>Leucheria achillaeifolia</i> *	2.52	15.75
<i>Medicago sativa</i>	3.60	22.50
<i>Melilotus</i> spp.	3.60	22.50
<i>Mulgranea-junellia</i> type*	3.72	23.25
<i>Oenothera</i> spp.*	2.14	13.37
<i>Pinus</i> spp. (a)	1.01	6.31
<i>Plantago</i> spp. (a)	2.13	13.30
<i>Populus</i> spp. (a)	2.64	16.50
Rosaceae	3.91	24.43
<i>Salix</i> spp.	2.03	12.68
<i>Schinus marchandii</i> *	3.50	21.80
<i>Senecio</i> spp.	2.69	16.80
<i>Sisyrinchium</i> spp.*	3.43	21.40
<i>Taraxacum officinale</i>	2.12	13.25
<i>Trifolium pratense</i>	3.67	22.90
<i>Trifolium</i> spp.	3.69	23.07
<i>Typha subulata</i> * (a)	1.50	9.37
<i>Ulmus</i> spp. (a)	1.98	12.37
<i>Valeriana clarionifolia</i> *	2.46	15.37
Fungal spore	1.17	7.31

*native plants; (a) wind-pollinated plants.

Protein content of collected pollen

Crude protein content of pollen from insect-pollinated plants ranged from 12.47% to 26.3%. Taxa with high levels (>20%) were *Adesmia* spp., Brassicaceae, *Convolvulus arvensis*, *Medicago sativa*,

Melilotus spp., *Mulgranea-junellia* type, Rosaceae, *Schinus marchandii*, *Sisyrinchium* spp., *Trifolium* spp. and *Trifolium pratense* L. (Table III). Low levels of protein were found in pollen from wind-pollinated plants and fungal spores. The most collected types had variable protein content.

Discussion

The results found in this work show that honey bees (*Apis mellifera*) collect between 55 and 163 g of pollen per colony daily. These values are similar to values obtained by other authors (e. g., Louveaux, 1968; O'Neal & Waller, 1984; Parent et al., 1990). In the north-western area of Santa Cruz, *Apis mellifera* uses a wide variety of resources, 42 taxa were recorded. However, this number represents only a part of the available supply in this area, where 140 species (excluding Poaceae) have been identified. A similar relation between available and used resources has been found in previous studies (e.g., Louveaux, 1968; Telleria, 1993; Basilio, 2000; Forcone, 2002; Andrada & Telleria, 2005; Dimou & Thrasyvoulou, 2007).

Of the total harvested taxa, only 15 had a biomass contribution over 1%. The most collected were Brassicaceae, *Taraxacum officinale*, Rosaceae (mainly *Prunus* spp.), *Salix* spp., *Convolvulus arvensis* and *Schinus marchandii*. The utilisation of a high number of sources and the intense exploitation of a few, is a typical foraging behaviour widely reported in *Apis mellifera* (e.g., O'Neal & Waller, 1984; Parent et al., 1990; Forcone, 2002; Dimou & Thrasyvoulou, 2007; Forcone et al., 2009). The utilisation of a great variety of pollen sources is considered a strategy to reduce the probability of nutrient deficiencies, and thereby promotes health and longevity of the colonies (Louveaux, 1990; Schmidt et al., 1995). The intense exploitation of a few resources is accordant with the

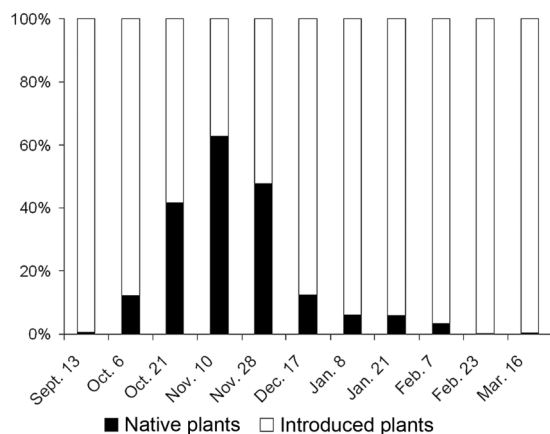


Figure 3. Biomass contribution of native and introduced plants.

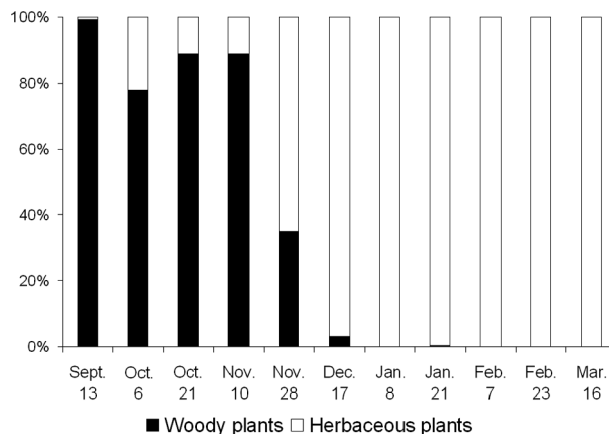


Figure 4. Biomass contribution of woody and herbaceous plants.

social foraging strategy of honey bees, since a colony focuses its forager force on few and high-quality food source patches within its foraging area (Visscher & Seeley, 1982).

The main represented families in terms of pollen type numbers are Asteraceae and Fabaceae. However, Asteraceae, Brassicaceae, Rosaceae and Salicaceae were the families with the greatest biomass contribution. These families have been recorded as important components of corbicular pollen by other authors as well (e.g., Louveaux, 1968; Parent et al., 1990; Tellería, 1993; Basilio, 2000; Bilisik et al., 2008).

In the study area, the pollen flow to the beehives is dominated by introduced floral elements. However, native flora is important in mid-spring collections. The period with the highest pollen contribution of the native flora corresponds to November, as this is the peak period of flowering for most native shrubs (Forcone & Muñoz, 2009). Similar results have been obtained in other arid and semiarid areas such as the Sonora desert (O'Neal & Waller, 1984), Monte (Forcone, 2002; Naab & Tamame, 2007) and Espinal (Andrada & Tellería, 2005).

Botanical composition of pollen loads reflected the flowering sequence during the apicultural period. The staggering of crops, shrub steppe and flowering weeds determined changes in the pollen load composition. Pollen collected shows a gradual replacement of woody plants (dominant at the beginning of the period) by herbaceous plants predominant at the end of the apicultural period. Similar results were obtained in the Lower Valley of Chubut River, another irrigated area of Patagonia (Forcone, 2002).

Collection of anemophilous pollen by *Apis mellifera* has been related to periods of low availability of entomophilous pollen (Severson & Parry, 1981; O'Neal & Waller, 1984; Forcone, 2002). Similarly, in this study the maximum collection of anemophilous pollen occurred at the end of winter, a period with scarce flowering of insect-pollinated plants (Forcone & Muñoz, 2009).

The comparison of the results of this research with those obtained by Forcone et al. (2009) shows that most plants providing pollen to the beehive are also sources of nectar. The taxa that stand out due to their contribution of pollen and nectar in the study area are Brassicaceae and Rosaceae, which provided 42% and 5.7%, respectively, to the collected pollen biomass and were also found as secondary pollen in the honey (Forcone et al., 2009). It is important to mention that, although *Melilotus* spp. and *Mulinum spinosum* are the main sources of nectar in the study area (Forcone et al., 2009), their pollen contribution to the hives is scarce (< 1%).

Data obtained in this work and previous research in the study area (Forcone et al., 2009; Forcone

& Muñoz, 2009) enabled to determine the main pollen plants used by *Apis mellifera*, their apicultural value and flowering period (Table IV). It is important to note that Astereae, *Taraxacum officinale* and Brassicaceae are pollen-nectariferous resources available during all the apicultural period.

Fifteen of the total pollen sources identified are new records for the pollen flora of Argentina and 13 of them are native plants of South America. Those include *Schinus marchandii*, *Mulinum spinosum*, *Leucheria achillaeifolia*, *Berberis microphylla*, *Ephedra ochreatea*, *Colliguaja integerrima*, *Adesmia* spp., *Phacelia secunda*, *Sisyrinchium* spp., *Oenothera* spp., *Acaena* spp., *Tropaeolum porifolium* and *Valeriana clarionifolia*.

The collection of fungal spores by *Apis mellifera* has been observed already by other authors (Shaw, 1999). In Argentina there is only one previous record (Andrada & Tellería, 2005). The observation of fungal spores in pollen loads in the present study is probably attributed to a lower availability of flowering plants in mid-summer (Forcone & Muñoz, 2009). However, some authors recorded the collection of fungal spores at times when flowers were present in the vicinity. It may be probable that fungal spores also contribute to honey bee diet (Shaw, 1999).

Protein content was lower in wind pollinated plants, mainly gymnosperms (Table III). Similar results have been found by other authors (e.g., Roulston et al., 2000). The most collected entomophilous pollen in the Santa Cruz Province had large differences in protein content. For example, *Salix* spp. and Asteraceae did not reach the minimum required (20%) to satisfy the nutritional needs of the beehive. Similar results were obtained by Van der Moezel et al. (1987), Forcone (2002) or Andrada and Tellería (2005). All these data are comparable with Roulston et al. (2000), who found that the richness in proteins is not a predominant factor in pollen collection. However, it is important to mention that the most harvested native pollen in the study area have protein content over 20%.

Conclusions

Apis mellifera utilises a wide spectrum of plants as sources of pollen in the north-western area of the Santa Cruz Province in Argentina. Fifteen of the taxa identified are new records for the pollen flora of Argentina. The species collected belong mainly to an exotic flora. The main pollen sources were Brassicaceae, *Taraxacum officinale*, *Convolvulus arvensis*, Rosaceae, *Salix* spp. and *Schinus marchandii*. Depending on the predominant types, the following seasonal variations are distinguished in the flow of pollen to hives during the apicultural period: end

Table IV. Main pollen sources in the area northwest of Santa Cruz (Argentina) with respective apicultural value, flowering and pollen-collection periods.

Taxa	Apicultural value	September	October	November	December	January	February	March
<i>Schinus marchandii</i> *	P-N		o	o				
Asteraceae *	P-N			o		o	o	o
<i>Senecio</i> spp.*	P-N			o	o			
<i>Taraxacum officinale</i>	P-N	o	o	o	o	o	o	o
Brassicaceae	P-N	o	o	o	o	o	o	o
<i>Convolvulus arvensis</i>	P-N			o	o	o	o	o
<i>Adesmia</i> spp.*	P-N			o				
<i>Sisyrinchium</i> spp.*	P-N	o	o					
<i>Plantago</i> spp. (a)	P			o	o	o	o	
Rosaceae	P-N	o	o					
<i>Acaena</i> spp.*	P-N			o	o	o		
<i>Salix</i> spp.	P-N	o	o					
<i>Populus</i> spp.(a)	P	o						
<i>Ulmus</i> spp. (a)	P	o						
<i>Mulgaraea-funellia</i> type*	P-N		o	o				

Bars indicate flowering periods; o, pollen collection; N, nectariferous; P, polliniferous; *native plants; (a) wind-pollinated plants [flowering periods extracted from Forcone and Muñoz (2009)].

of winter: Salicaceae; beginning of spring: Rosaceae; mid spring: *Schinus marchandii*, Asteraceae (mainly *Taraxacum officinale*) and Brassicaceae; end of spring and during summer: Brassicaceae and *Convolvulus arvensis*. Most plants that provide pollen to the bee-hive are also nectariferous resources, but pollen from main nectar sources is scarcely collected.

The highest contribution of native flora occurs in mid spring, reaching its maximum in November. *Schinus marchandii*, *Mulgaraea-funellia* type, *Adesmia* spp., *Sisyrinchium* spp., *Acaena* spp., *Senecio* spp. and Asteraceae were the most collected indigenous pollen types; between them, *Schinus marchandii*, *Mulgaraea-funellia* type, *Adesmia* spp. and *Sisyrinchium* spp. stand out due to their high percentage of protein content (>20%).

Acknowledgements

We thank the Science and Technique Secretary of the Universidad Nacional de la Patagonia, San Juan Bosco, for its budget contribution.

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