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Availability of Nectar and Pollen Sources for Honey Bees in Oman

Hossam F. Abou-Shaara

Department of Plant Protection, Faculty of Agriculture, Damanhour University, Damanhour, 22516, Egypt
E-mail: hossam.farag@agr.dmu.edu.eg

KEYWORDS Colonies. Feeding Flowering. Flora. Plants

ABSTRACT Currently, beekeeping contributes in the economic development of many countries. This agricultural activity has gained more attention in various countries during the last few years, and beekeeping activities are increasing rapidly in Oman. The availability of many food sources to honey bees is very essential for the development of beekeeping. Thus, listing potential honey bee plants is very essential to help boosting beekeeping. In this paper, previous studies on honey bee plants in Oman as well as potential honey bee plants are reviewed. In fact, few studies have been conducted on bee plants in Oman. A good number of plant species including fruits, field crops, vegetables and wild plants that can feed honey bees were surveyed as shown in this review. The flowering period of these plants can cover the whole year. This study can be considered as an essential step towards understanding the bee flora in Oman.

INTRODUCTION

Honey bees, *Apis mellifera*, are considered as major pollinators to many plants (Morse and Calderone 2000; Reyes-Carrillo et al. 2007; Blazyte-Cereskiene et al. 2010), and additional benefits from honey bees can be obtained including the valuable products from the colonies; honey, pollen and royal jelly. Therefore, honey bees can be considered as sources of income for many people and as means for rural development (Chazovachii et al. 2013; Qaiser et al. 2013). It is well known that honey bees depend on plants to gather carbohydrate food (that is, nectar) as well as protein food (that is, pollens) (Crailsheim et al. 1992; Huang 2012; Abou-Shaara 2014; Abou-Shaara 2015a).

Objective

Increasing beekeeping activity is highly related to the availability of honey bee plants. Thus, listing these plants and classifying them according to their potential benefit to honey bees are essential to help enhance beekeeping (Abou-Shaara 2015b). In this review, potential honey bee plants in Oman are reviewed to realize this objective.

OBSERVATIONS

Omani Beekeeping

The Sultanate of Oman is located in the south eastern corner of the Arabian Peninsula with a total area of about 300,000 km^2. Oman is generally considered a sub-tropical country with hot and dry climate. Coastal areas of Northern Oman and Musandam receive irregular rains mostly during autumn, winter and early spring, with interior areas and mountains receiving additional rains. The coastal areas and south-facing mountains of the southern region of Dhofar are affected by the monsoon starting in mid to late June and until mid to late September, with the remaining months being generally rainless but mostly humid. The central area of Oman is very dry and windy most of the year with high temperature. The eastern side of northern Oman is occasionally affected by storms. The topographic features of Oman include the Hajar mountains of northern Oman, and the famous mountains are Jabal AlAkhdhar and Jabal Shams, which contain the highest peak in Oman.

Two species of honey bees are present in Oman: the dwarf honey bee (*Apis florea* Fabricius) (Dutton and Simpson 1977; Whitcombe

1984) and the Yemeni honey bee (*Apis mellifera jemenitica* Ruttner) (Dutton et al. 1981). The latter is cultured using traditional and modern methods while the former is generally wild but can be kept temporarily using traditional methods. The two species are found throughout Oman, although the dwarf honey bee is more common in northern Oman (Dutton and Simpson 1977). Moreover, the importation of common honey bee races and hybrids is done actively including hybrids of Carniolan honey bees from Egypt.

In Oman, common honey bees are kept in both traditional (log hives) and modern hives (Langstroth hives). Dwarf honey bees combs are raised or kept temporarily by some beekeepers in northern Oman, by hanging the comb containing brood and adults bees (remaining after removal of top honey-containing portion) using two sticks in its original position or in nook or opening in walls in cultivated/farm area close to where beekeeper resides. The majority of the wild honey bee hives in northern Oman are those of the dwarf honey bee, while in Dhofar they have been mostly of the common honey bee.

There are two major honey flow seasons in northern Oman, autumn honey flow from October to December and spring honey flow from March to May. In coastal mountain areas, a major honey flow after the end of the monsoon extending from late September to late November is present (Sajwani and Farooq 2014). Omani bee honeys are renowned for their good taste and nutritional value and are not rapidly crystallized (Sajwani et al. 2007). The honey production per colony per year ranged from 2 to 10 kg with mean of 5.50 kg (Al-Ghamdi et al. 2016).

Potential Honey Bee Plants in Oman

Sajwani et al. (2014) found that the major bee plants were *Ziziphus spina-christi*, *Acacia tortilis*, *Citrus* spp., *Zygophyllum* spp., *Prosopis cineraria*, *Prosopis juliflora*, *Maerua crassifolia*, and *Fagonia* spp in Oman. Popova et al. (2013) studied properties of Omani propolis and considered *Azadirachta indica* as the most important source for propolis followed by some other plants including *Acacia* spp. (*A. nilotica*) and *Mangifera indica*. The potential bee plants in Oman are listed according to their benefits to honey bees as source of nectar/pollen, and flowering season; spring (March to May), summer (June to August), autumn (September to November), and winter (December to February) as shown in the next paragraphs. The work of Al-Zidjali (1996), GAAP and ACSAD (2015) and Abou-Shaara (2015b) were utilized to prepare this list of plants, and another references were used to identify the potential benefit of these plants to honey bees as source of nectar, pollen or both.

1. Field Crops

Nectar Plants: Winter: *Brassica juncea* (Fam. Brassicaceae) (Ali et al. 2011).

Pollen Plants: Summer: *Sorghum bicolor* (Fam. Poaceae) (Morton 1964; Shawer 1987; Adjaloo and Yeboah-Gyan 2003; Schmidt and Bothma 2005; Ismail et al. 2013; Abou-Shaara 2015a).

Nectar and Pollen Plants: Spring: *Linum* sp. (Fam. Linaceae), while during summer/autumn *Gossipium* spp. (Fam. Malvaceae), *Helianthus annuus* (Fam. Asteraceae), *Medicago sativa* (Fam. Fabaceae), *Sesamum indicum* (Fam. Pedaliaceae) (Morton 1964; McGregor 1976; Hussein 2001; Bhuiyan et al. 2002; Alghoson 2004; Ismail et al. 2013; Kamel et al. 2013; Shubharani et al. 2013; Abou-Shaara 2015a).

2. Vegetables

Nectar Plants: Spring/summer: *Abelmoschus Esculentus* (Fam. Malvaceae) and *Vigna sinensis* (Fam. Fabaceae) (McGregor 1976; Mishra et al. 1987).

Pollen Plants: Spring: *Cucumis* sp. (Fam. Cucurbitaceae) (Sivaram, 2001) while during summer/autumn; *Asparagus* spp. (Fam. Asparagaceae) and *Corchorus* sp. (Fam. Malvaceae) (McGregor 1976).

Nectar and Pollen Plants: Winter/spring: *Citrullus* spp. (Fam. Cucurbitaceae) and *Vicia faba* (Fam. Fabaceae) (McGregor 1976; Morton 1964; Shawer 1987; Taha and Bayoumi 2009).

Not Specified: Summer: *Cicer arietinum* (Fam. Fabaceae) but its benefit to bees has not been studied.

3. Fruit Trees

Nectar Plants: Spring: *Citrus limon* (Fam. Rutaceae(and *Prunus persica* (Fam. Rosaceae) (Morton 1964; Alghoson 2004). Summer/autumn:

Mangifera sp. (Fam. Anacardiaceae) and *Musa acuminate* (Fam. Musaceae) (Suryanarayana et al. 1992).

Pollen Plants: Spring/summer: *Phoenix dactylifera* (Fam. Arecaceae), *Prunus armeniaca* (Fam. Rosaceae) and *Vitis* spp. (Fam. Vitaceae) (Morton 1964; McGregor 1976; Alghoson 2004; Ismail et al. 2013).

Nectar and Pollen Plants: Spring/summer: *Carica* sp. (Fam. Caricaceae), *Cocos* sp. (Fam. Arecaceae), *Citrus* spp. (Fam. Rutaceae), *Citrus aurantifolia* (Fam. Rutaceae), *Psidium guajava* (Fam. Myrtaceae), *Malus* sp. (Fam. Rosaceae), *Prunus Amygdalus* (Fam. Rosaceae) and *Pyrus* spp. (Fam. Rosaceae), (Morton 1964; McGregor 1976; Suryanarayana et al. 1992; Sivaram 2001; Adjaloo and Yeboah-Gyan 2003; Alghoson 2004; Anita et al. 2012; Ismail et al. 2013; Shubharani et al. 2013).

Not Specified: Summer and autumn; *Annona* sp. (Fam. Annonaceae), *Ficus* spp. (Fam. Moraceae), *Punica granatum* (Fam. Lythraceae).

4. Medicinal, Aromatic, Ornamental, and Wild Plants

Nectar Plants: Spring: *Astragalus* sp. (Fam. Fabaceae), *Boswellia Sacra* (Fam. Burseraceae), *Capparis cartilaginea* (Fam. Brassicaceae), *Diplotaxis harra* (Fam. Brassicaceae), *Salvia* sp. (Fam. Lamiaceae), *Heliotropium* sp. (Fam. Boraginaceae), *Ziziphus hajarensis* (Fam. Rhamnaceae), *Ziziphus mauritiana* (Fam. Rhamnaceae) (Morton 1964; Alghoson 2004; GAAP and ACSAD 2015).

Summer: Blepharis ciliaris (Fam. Acanthaceae), *Avicennia marina* (Fam. Avicenniaceae), *Heliotropium europaeum* (Fam. Boraginaceae), *Heliotropium longiflorum* (Fam. Boraginaceae), *Cleome* sp. (Fam. Cleomaceae), *Cleome glaucescens* (Fam. Cleomaceae); *Ipomoea* sp. (Fam. Convolvulaceae), *Ocimum* spp. (Fam. Lamiaceae), *Salvadora persica* (Fam. Salvadoraceae), *Dodonaea viscosa* (Fam. Sapindaceae), *Cissus* sp. (Fam. Vitaceae) (Morton 1964; Sivaram 2001; Alghoson 2004; Kumar et al. 2012; GAAP and ACSAD 2015).

Pollen Plants: Spring: *Fagonia indica* (Fam. Zygophyllaceae), *Tribulus* spp. (Fam. Zygophyllaceae), *Zygophyllum* spp. (Fam. Zygophyllaceae), *Grewia* sp. (Fam. Sparrmanniaceae), *Reseda aucheri* (Fam. Resedaceae), *Pteropyrum scoparium* (Fam. Polygalaceae), *Reseda muricata* (Fam. Resedaceae), *Olea europaea* (Fam. Oleaceae), *Ceratonia Oreothauma* (Fam. Fabaceae), *Cassia* sp. (Fam. Fabaceae), *Maerua crassifolia* (Fam. Brassicaceae), *Centaurea pseudosinaica* (Fam. Asteraceae), *Achyranthes aspera* (Fam. Amaranthaceae) (Morton 1964; Sivaram 2001; Ismail et al. 2013; Bhalchandra et al. 2014; Sajwani et al. 2014; Abou-Shaara 2015a; GAAP and ACSAD 2015).

Summer: Amaranthus spp. (Fam. Amaranthaceae), *Cynodon dactylon* (Fam. Poaceae), *Pennisetum* sp. (Fam. Poaceae), *Pennisetum typhoides* (Fam. Poaceae), *Pulicaria argyrophylla* (Fam. Asteraceae), *Pulicaria glutinosa* (Fam. Asteraceae), *Pulicaria undulate* (Fam. Asteraceae), (Roubik 1995; Sivaram 2001; Bhuiyan et al. 2002).

Autumn: Tamarix aphylla (Fam. Tamaricaceae), *Fagonia bruguieri* (Fam. Zygophyllaceae), *Datura* sp. (Fam. Solanaceae), *Cucumis* sp. (Fam. Cucurbitaceae) (Sivaram 2001).

Nectar and Pollen Plants: Spring: *Acacia Gerradii* (Fam. Fabaceae), *Acacia ehrenbergiana* (Fam. Fabaceae), *Acacia nilotica* (Fam. Fabaceae), *Acacia Senegal* (Fam. Fabaceae), *Acacia tortilis* (Fam. Fabaceae), *Abelmoschus* sp. (Fam. Malvaceae), *Aloe vera* (Fam. Asphodelaceae), *Berberis* sp. (Fam. Berberidaceae), *Bidens pilosa* (Fam. Asteraceae), *Convolvulus arvensis* (Fam. Convolvulaceae), *Convolvulus cephalopodus* (Fam. Convolvulaceae), *Convolvulus virgatus* (Fam. Convolvulaceae), *Crotalaria* sp. (Fam. Fabaceae), *Chenopodium* sp. (Fam. Chenopodiaceae), *Euphorbia* sp. (Fam. Euphorbiaceae), *Helichrysum glumaceum* (Fam. Asteraceae), *Moringa* sp. (Fam. Moringaceae), *Reichardia tingitana* (Fam. Asteraceae) (Morton 1964; Sivaram 2001; Alghoson 2004; Rashmi et al. 2008; Izhar-ul-Haq et al. 2001; Dafalla 2011; Gorain et al. 2012; Shubharani et al. 2013).

Summer: Abutilon sp. (Fam. Malvaceae), *Azadirachta indica* (Fam. Meliaceae), *Capparis spinosa* (Fam. Brassicaceae), *Sideroxylon* sp. (Fam. Sapotaceae) (Sivaram 2001: Alghoson 2004: Saibal 2005: Taha 2015).

Autumn: Caesalpinia sp. (Fam. Leguminosae), *Hammada* sp. (Fam. Chenopodiaceae), *Impatiens balsamina* (Fam. Balsaminaceae), *Ricinus communis* (Fam. Euphorbiaceae), (Morton 1964; Sivaram 2001).

Winter: Aloe vera (Fam. Asphodelaceae), *Prosopis cineraria* (Fam. Fabaceae), *Prosopis juliflora* (Fam. Fabaceae), *Thymus vulgaris* (Fam. Lamiaceae), *Ziziphus spina-christi* (Fam. Rhamnaceae) (Morton 1964; Alghoson 2004; Torné-Noguera et al. 2016).

Not Specified: Autumn/ winter: *Aeluropus lagopoides* (Fam. Poaceae), *Aeluropus littoralis* (Fam. Poaceae), *Atriplex farinose* (Fam. Chenopodiaceae), *Atriplex leucoclada* (Fam. Chenopodiaceae), *Apluda mutica* (Fam. Poaceae), *Aerva javanica* (Fam. Amaranthaceae), *Boscia Arabica* (Fam. Brassicaceae), *Dactyloctenium aegyptium* (Fam. Poaceae), *Dipterygium glaucum* (Fam. Brassicaceae), *Dyschoriste dalyi* (Fam. Acanthaceae), *Farsetia aegyptia* (Fam. Brassicaceae), *Limonium stocksi* (Fam. Plumbaginaceae), *Lotus garcinii* (Fam. Fabaceae), *Lycium shawii* (Fam. Solanaceae), *Morettia parviflora* (Fam. Brassicaceae), *Nannorrhops ritchiana* (Fam. Palmae), *Periploca aphylla* (Fam. Apocynaceae), *Pergularia tomentosa*, (Fam. Apocynaceae), *Plantago ovate* (Fam. Plantaginaceae), *Plumbago zeylanica* (Fam. Plumbaginaceae), *Ruttya fruticosa* (Fam. Acanthaceae), *Senna italic* (Fam. Fabaceae), *Senra incana* (Fam. Malvaceae).

Spring/Summer: Acridocarpus orientalis (Fam. Malpighiaceae), *Anagallis arvensis* (Fam. Primulaceae), *Andrachne telephioides* (Fam. Euphorbiaceae), *Anogeissus dhofarica* (Fam. Combretaceae), *Arnebia decumbens* (Fam. Bignoniaceae), *Arnebia hispidissima* (Fam. Bignoniaceae), *Anastatica hierochuntica* (Fam. Brassicaceae), *Aizoon canariense* (Fam. Aizoaceae), *Aizoon hispanicum* (Fam. Aizoaceae), *Ammi majus* (Fam. Apiaceae), *Aristida mutabilis* (Fam. Poaceae), *Asphodelus tenuifolius* (Fam. Liliaceae), *Boerhavia rubicunda* (Fam. Nyctaginaceae), *Calligonum comosum* (Fam. Polygalaceae), *Calotropis procera* (Fam. Apocynaceae), *Chloris barbata* (Fam. Poaceae), *Chrozophora oblongifolia* (Fam. Euphorbiaceae), *Commicarpus helenae* (Fam. Nyctaginaceae), *Cressa cretica* (Fam.Convolvulaceae),*Cornulaca aucheri* (Fam.Chenopodiaceae),*Cornulaca monacantha* (Fam. Chenopodiaceae), *Cucumis prophetarum* (Fam. Cucurbitaceae), *Cymbopogon schoenanthus* (Fam. Poaceae),*Cyperus conglomeratus* (Fam. Cyperaceae), *Daphne mucronata* (Fam. Thymelaeaceae), *Dionysia mira* (Fam. Primulaceae), *Ebenus stellate* (Fam. Fabaceae), *Ephedra pachyclada* (Fam. Ephedraceae), *Euryops arabicus* (Fam. Asteraceae), *Erdium laciniatum* (Fam. Geraniaceae), *Forsskaolea tenacissima* (Fam. Urticaceae), *Ficus cordata* (Fam. Moraceae), *Haplophyllum tuberculatum* (Fam. Rutaceae), *Helianthemum lippii* (Fam. Cistaceae), *Indigofera intricate* (Fam. Fabaceae), *Indigofera oblongifolia* (Fam. Fabaceae), *Indigofera Arabica* (Fam. Fabaceae), *Imperata cylindrica* (Fam. Poaceae), *Juniperus excels* (Fam. Cupressaceae), *Launaea capitata* (Fam. Asteraceae), *Lasiurus scindicus* (Fam. Poaceae), *Leptadenia pyrotechnica* (Fam. Apocynaceae), *Lomelosia olivieri* (Fam. Dipsacaceae), *Malva neglecta* (Fam. Malvaceae), *Malva parviflora* (Fam. Malvaceae), *Melhania muricata* (Fam. Sterculiaceae), *Myrtus communis* (Fam. Myrtaceae), *Ochradenus arabicus* (Fam. Resedaceae), *Ochradenus aucheri* (Fam. Resedaceae), *Plocama aucheri* (Fam. Rubiaceae), *Panicum turgidum* (Fam. Poaceae), *Phalaris minor* (Fam. Poaceae), *Physorhynchus chamaerapistrum* (Fam. Brassicaceae), *Pistacia* sp. (Fam. Anacardiaceae), *Polygala mascatensis* (Fam. Polygalaceae), *Portulaca oleracea* (Fam. Portulacaceae), *Rumex vesicarius* (Fam. Polygalaceae), *Setaria Pumila* (Fam. Poaceae), *Taverniera cuneifolia* (Fam. Fabaceae), *Tecomella undulate* (Fam. Bignoniaceae), *Tephrosia nubica* (Fam. Fabaceae), *Tephrosia purpurea* (Fam. Fabaceae), *Tetraena qatarensis* (Fam. Zygophyllaceae), *Tetraene simplex* (Fam. Zygophyllaceae), and *Viola cinerea* (Fam. Violaceae).

DISCUSSION

A total of 198 plant species with potential benefit to honey bees were surveyed. These plants are included in 71 plant families, and the highest representative percentage of plants is from Fam. Fabaceae (11.67% of the plants) followed by Fam. Poaceae (9.13%), Fam. Brassicaceae (6.6%), Fam. Asteraceae (5.07%), and Fam. Malvaceae (4.06%). The other families represent less than 4 percent of the plants. According to the benefit to honey bees (Table 1), 22 percent of plants result as pollen and nectar sources (mainly wild and fruit plants), 17 percent of plants as pollen sources (mainly wild plants), and 13 percent as nectar sources (main-

Table 1: Percentage of plants according to their benefit to honey bees as sources of nectar, pollen or both of them

Benefit to bees (total percentage)	*Plant type (%)*			
	Field crops	*Vege-tables*	*Fruit trees*	*Wild plants*
Pollen (17%)	7	10	10	73
Nectar (13%)	4	7	15	74
Pollen and nectar (22%)	11	5	19	65
Not specified (48%)	0	1	3	96

ly wild and fruit plants). The percentage of plants with unspecific benefit to honey bees reached 48 percent. The benefits of 96 percent of surveyed wild plants were not available in the literature, suggesting lacking of studies.

According to the flowering time of the surveyed plants (Table 2), the flowering of the majority of plants occur during spring (55%, mainly from wild and fruit plants), 21 percent during summer (mainly from wild and fruit plants), 11 percent during fall (mainly from wild plants and field crops), and 13 percent during winter (mainly from wild plants). This reflects the availability of food sources to honey bees over the year.

Table 2: Percentage of plants according to their flowering season

Seasib (total) percentage)	*Plant type (%)*			
	Field crops	*Vege-tables*	*Fruit trees*	*Wild plants*
Winter (13%)	4	4	8	84
Spring (55%)	1	5	9	85
Summer (21%)	12	10	23	55
Autumn (11%)	18	9	14	59

CONCLUSION

There are a good number of plants as natural food sources to honey bees in Oman with a total of 198 plant species. These plants can be classified as sources of pollen/nectar, pollen, and nectar with percentages of 22 percent, 17, and 13, respectively. These sources can cover the whole year to support beekeeping development. The percentage of plants with unspecific benefit to honey bees was 48 percent. Plants with unspecific benefits to honey bees require further investigations. Also, classifying plants as major, moderate or minor sources to pollen or nectar need future studies. Identifying the distribution of the flowering plants in Oman is very essential to guide beekeepers. According to season, beekeepers can track flowering plants utilizing the list presented in this study.

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