An overview of beekeeping in the Kingdom of Saudi Arabia

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Abstract

In recent years honey bee colonies have been seriously affected by colony losses, with implications for their future existence. Much has been written about beekeeping, honey bee management practices and colony losses in many developed countries, but relatively little has been written about these topics in Saudi Arabia. This overview provides a brief insight into races of honey bees and beekeeping in Saudi Arabia. It also examines some important factors which have an impact on beekeeping within Saudi Arabia, including climatic factors and availability of forage. Main challenges faced by beekeepers in Saudi Arabia are discussed. Some conclusions are that honey is a much sought-after product in Saudi Arabia, and it is important for the economy to be able to meet this demand. As a result of the lucrativeness of the beekeeping industry, many have taken up beekeeping, but the industry lacks an overall structure, and lack of information and communication amongst beekeepers can mean that issues are not easily resolved. Hence, there is a need to gain more in-depth knowledge of beekeeping in Saudi Arabia, and in particular to identify common practices and challenges faced, so that trends, solutions, and best practices can be identified. Identification of aspects of beekeeping in Saudi Arabia which could be improved will be beneficial to all stakeholders involved in beekeeping in Saudi Arabia.

Keywords: honey bee subspecies; *Apis mellifera jemenitica*; beekeeping practices; climate; forage; migration; challenges; structure and organisation of beekeeping

1. Introduction

While there is an extremely extensive research literature concerning honey bees, relatively little of this is concerned with less developed countries, including those in the Middle East. In this article, we focus on honey bees and beekeeping in Saudi Arabia.

Beekeeping is an important industry in many rural communities in the Kingdom of Saudi Arabia (KSA), and a long-standing practice with a vital role in the economic activities of the country. There are about one million honey bee colonies, owned by more than 5,000 beekeepers, in Saudi

Arabia (Al-Ghamdi & Adgaba, 2015a). Alqarni et al. (2011) describe 4,000 beekeepers and 700,000 colonies producing about 3,500 tons of honey annually, which only fulfil about a quarter of the demand for honey, while Europe, Iran, Turkey, Australia and the USA provide most of the remaining 10,000 tons of honey required to meet demand. Taha (2015) cites annual honey production of about 9,000 tons, satisfying about half of the demand, and about 9,000 tons being imported. It is clear that beekeeping is a growing industry in Saudi Arabia, with much potential for further expansion.

Apis mellifera jemenitica Ruttner is the most important, and also the indigenous, honey bee race in Saudi Arabia (Al-Ghamdi & Adgaba, 2015a), which can cope well with the high temperatures and low rainfall (Ruttner, 2013), short flowering period and long dry period (Al-Ghamdi & Adgaba, 2015a). Beekeeping in KSA takes place mainly in the south-western regions of Asir, Baha and Taif, which are mountainous (Alqarni et al., 2011) (Figure 1).

Although traditional hives are the most popular among beekeepers in Saudi Arabia (Al-Ghamdi & Adgaba, 2015a), modern box hives can also be found in different parts of the country. Beekeepers practise migratory beekeeping in many areas of Saudi Arabia. The main plant families important as forage sources for honey bees in Saudi Arabia include *Fabaceae*, *Lamiaceae* and *Rhamnaceae (*Alqarni et al., 2011; Adgaba et al., 2017a). Challenges in beekeeping in KSA include the extreme weather, diseases and parasites, as well as the issue of indigenous bee colonies providing low honey yield.

Several authors have studied aspects of beekeeping in Saudi Arabia, especially in the last few years, however some of these useful publications are available only in Arabic. In this article, we aim to provide a short overview of bee races, beekeeping status, practice and challenges in Saudi Arabia, to give a picture which may be of interest to a wider readership. Section 2 provides an overview of the history of beekeeping in Saudi Arabia, and the development of the industry in the country. Section 3 provides details of the subspecies of honey bees which are indigenous to the country and describes their characteristics, while Section 4 outlines current beekeeping practices in KSA. Section 5 provides details of the main forage plants within Saudi Arabia, conditions and foraging activity that occurs in the country. Section 6 identifies some of the main challenges faced by beekeepers in Saudi Arabia. Section 7 outlines the structure and organisation of beekeeping in KSA, and Section 8 provides a summary and conclusions.

2. History of beekeeping in KSA

Beekeeping has a very long history which can be traced back several millennia (Dams, 1978). Human beings first acted as honey-hunters, collecting honey from feral honey bee colonies, dating back to at least 6,000 BC (Dams, 1978; Roffet-Salque et al., 2015). Then, humans started to domesticate wild bees, becoming beekeepers, from at least 4,500 years ago (Crane, 2013). The exact time and place of the start of beekeeping in Saudi Arabia is unknown, as there is no written evidence indicating these, but rock paintings indicate that beekeeping in the Pre-Islamic Arabia or 'Arabian Peninsula' dates back to at least 2,000 BC (Alqarni et al., 2011).

After the rise of Islam in the 7th century, the importance of honey greatly increased in Saudi Arabia. One chapter of The Holy Qur'an, the central religious text of Islam, was entitled "Al-Nahl", which means 'The Bees' (Alqarni et al., 2011; Al-Ghamdi & Adgaba, 2015a). The Holy Qur'an mentions many advantages of honey, including being used as a remedy to treat numerous diseases. Since then there has been a considerable increase in beekeeping in Saudi Arabia as people have become more interested in honey and its properties (Al-Ghamdi & Adgaba, 2015a). The oldest apiaries in Saudi Arabia can be found in Taif, in the south-western area, and are about 500 years old (Alqarni et al., 2011).

A new phase in beekeeping began over 150 years ago (Alqarni et al., 2011), when the Langstroth bee hive, patented in 1852, was introduced (Langstroth, 1853). Today, management of honey bee colonies, commonly in man-made hives, is now more advanced and up-to-date in KSA (Alqarni et al., 2011). Saudi Arabia is well acquainted with the many methods and improvements that have been made in the beekeeping industry, as well as its traditional beekeeping practices (Alqarni et al., 2011), although many beekeepers have yet to adopt more modern methods of beekeeping.

3. Diversity and morphology of honey bees in KSA

Engel (1999) identified 28 subspecies of *Apis mellifera* in the Mediterranean, Central Asia, Southern Europe, and in African-Arabian regions, of which *Apis mellifera jemenitica ,* the Yemeni honey bee*,* is the honey bee native to KSA and is the most dominant race in KSA, which is mostly used in traditional beekeeping (Al-Ghamdi & Adgaba, 2015a). Alqarni et al. (2011) state that about 70% of honey bees managed in KSA are the native *A. m. jemenitica*, while others are *A. m. carnica*,

mostly imported from Egypt, or, to a lesser extent, *A. m. ligustica*, imported from Jordan (Iqbal et al., 2019). *A. m. jemenitica* in KSA is unique in many ways. From the morphological and biological perspective it is different from other populations of the same race in Africa (Alqarni, 1995; Al-Ghamdi, 2006).

Temperature and humidity are two of the most important factors for honey bee colonies (Abou-Shaara et al., 2012). Temperatures lower than 10°C (Joshi & Joshi, 2010) and higher than 36°C (Petz, Stabentheiner, & Crailsheim, 2004) are not suitable for honey bee colonies. The temperature in many parts of Saudi Arabia is not within this comfortable range for honey bees, as it is higher in summer and can be lower in winter. Compared to other subspecies, *A. m. jemenitica* is more able to cope with this high temperature of about 40°C (Ruttner, 2013). Average annual rainfall in Saudi Arabia is only about 100 mm, and *A. m. jemenitica* is also well adapted to these dry conditions (Ruttner, 2013). The brief flowering period and long dry period, which leads to arid and desert conditions, suit *A. m. jemenitica* (Al-Ghamdi & Adgaba, 2015a). In a study of the effects of temperature and relative humidity on Yemeni and Carniolan forager bees, Abou-Shaara et al. (2012) found that Yemeni bees were more tolerant of extreme high temperatures or low humidity than Carniolan bees. Alqarni (2006) found *A. m. jemenitica* more active in foraging in the summer temperatures of Riyadh than *A. m. carnica* or *A. m. ligustica*, in a comparison of indigenous and imported honey bees.

Morphologically, the Saudi Arabian population of honey bees is a distinct ecotype of *A. m. jemenitica* (Ruttner, 2013). This native population of Saudi Arabia is smaller and more slender compared to some other races (Ruttner, 2013; Robinson & Abrol, 2000), and also compared to other populations of *A. m. jemenitica* in the area (Alaqarni et al., 2011), though Oldroyd &Wongsiri (2006) reported that *A. m. cerana* and *A. m. jemenitica* are almost the same size. According to Al-Ghamdi (2005), the number of worker cells per unit area for *A. m. jemenitica* in traditional beekeeping is 25% more than European honey bees produce on wax comb foundation. In addition, the population of *A. m. jemenitica* in KSA has been reported as behaving differently to the population of *A. m. jemenitica* in South Africa (Al-Ghamdi & Adgaba, 2015a). For example, it is easier to work with the *A. m. jemenitica* of Saudi Arabia with minimum protection than with the *A. m. jemenitica* of South Africa, as the *A. m. jemenitica* population in KSA is reported to be gentle and calm in nature (Robinson & Abrol, 2000).

4. Current beekeeping practice in KSA

Regions where beekeeping is practised: Saudi Arabia is a vast country, with diverse environmental and climatic conditions. It consists of lowlands as well as extensive mountain ranges (Figure 1). The mountain chains can provide sufficient amounts of rainfall to help grow plants which provide a rich source of nectar and pollen (Al-Ghamdi & Adgaba, 2015a), and the summer temperature in the mountain region (20°C to 28°C) is suitable for honey bees. Though beekeeping is practised all over Saudi Arabia, the rainfall and temperature have made the south-western mountainous region the most suitable area for beekeeping (Al-Ghamdi & Adgaba, 2015a). This region comprises about 762,474 acres of forested land (Alqarni et al., 2011) and includes Al-Baha, Mekkah, Al-Medinah and Asir (Figure 1). Only 30% of the beekeeping in Saudi Arabia can be found in places outwith this region (Al-Ghamdi & Adgaba, 2015a). Traditional beekeeping is the most common in the south-west, while box hives are used more in other areas (Alqarni et al., 2011).

To protect colonies from severe weather and food deficiency, beekeepers in Saudi Arabia tend to practise migratory beekeeping. This differs from the motivation for migration in some other parts of the world, where migration is practised for purposes of commercial pollination, or for access to forage sources producing high honey yields or honey attracting a high price. Temperature, flowering season, and availability of botanical sources of nectar and pollen play important roles in selecting the place to which beekeepers move their bees in KSA (Alqarni et al., 2011). For example, Tihama is a coastal region in the west, along the Red Sea, with plenty of pollen plants, which attracts beekeepers to move their bees there in winter. Migration may occur from the south to the west, to the centre, or to the north, and in the other direction (Alqarni et al., 2011). Some beekeepers may migrate their colonies several times a year (Al-Ghamdi & Adgaba, 2015a).

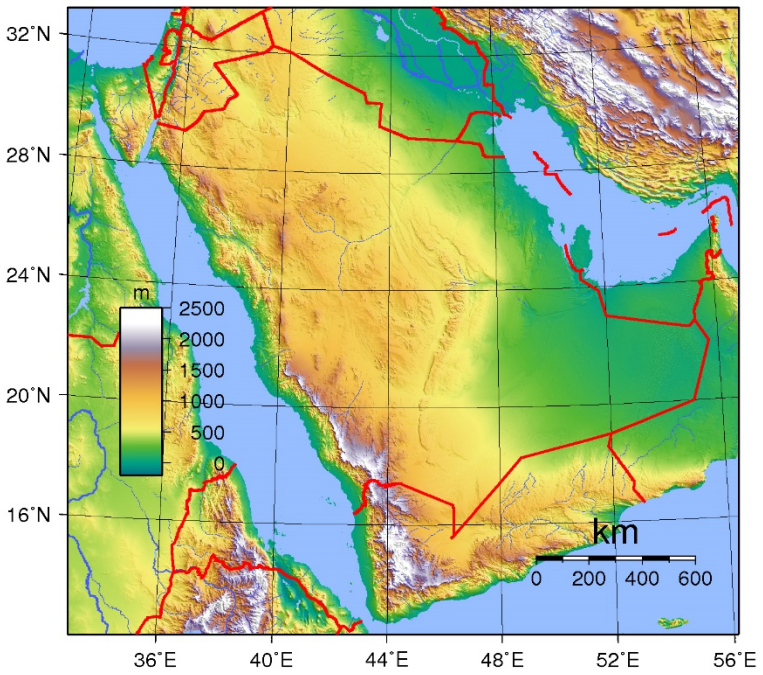

Figure 1. Relief map of Saudi Arabia, showing the south-western mountain region. Source: http://www.maps-of-the-world.net/maps/maps-of-asia/maps-of-saudi-arabia/large-topographical-map-of-saudi-arabia.jpg ; public domain image licensed under CC BY-SA 3.0.

Hive types: Traditional hives made from local materials are still dominant in Saudi Arabia, and the majority of beekeepers use these. Al-Ghamdi & Adgaba (2015a) cite more than 70% of beekeepers as using traditional hives, while Adgaba et al. (2014) in a study of 182 beekeepers across 5 regions found 62.4% of beekeepers using traditional hives and 71.1% of colonies were kept in traditional hives. One reason is that demand for honey collected from traditional hives is high, because consumers and beekeepers believe that honey from such hives is of higher quality and has higher viscosity than honey from other types of hive (Al-Ghamdi & Adgaba, 2015a). It is also convenient for beekeepers to use traditional hives, for many reasons. For example, it is cheap, hives can be made with available materials, and they have better insulation properties, which is important in extremely hot weather. Difficulty in migrating colonies kept in box hives is another reason, and local bees are believed to be better suited to traditional hives than box hives (Adgaba et al., 2014), for example due to the small size of *A. m. jemenitica*.

Clay pot hives, mud hives, and log hives are some of the common traditional hives (Robinson & Abrol, 2000), of which log hives (Figure 2) are the most popular and are found in two outer shapes, rectangular and round (Al-Ghamdi & Adgaba, 2015a), made from date palm tree trunks and

processed timber from other trees. Today, machine-made timber is assembled to make the cylindrical form of log hives. Even many commercial beekeepers use such hives. Sometimes traditional hives are kept stacked, to save space, create shelter, and as it is then faster to inspect the hives and harvest the honey (Al-Ghamdi & Adgaba, 2015a). In traditional hives, combs are squeezed or cut to extract the honey, which is then strained through cotton cloth (Hussein, 2000), while beekeepers with modern box hives may use honey extractors (Al-Ghamdi & Adgaba, 2015a). Al-Ghamdi & Adgaba (2015a) cite average honey production per annum of 3-5kg for a traditional hive compared to 5-10kg for a box hive. Adgaba et al. (2014) and Al-Ghamdi et al. (2017b) cite corresponding averages of 3.7kg and 6.6kg per hive. In a survey of beekeepers in 14 Arab countries, Al-Ghamdi et al. (2016) found that the Saudi beekeepers reported an average of 4.10kg of honey produced per colony per year, which was one of the lowest in the countries included in the study.

Figure 2. Left: Traditional beehives assembled in a hollowed trunk log; Right: Bees inside the wooden hive. Source: https://pcela.rs/yemeni_honeybees.htm, included with kind permission of Hossam Abou-Shaara, of Damanhour University, Egypt.

Modern box hives or Langstroth-type hives (Langstroth, 1853) are also found in some places in Saudi Arabia, since the 1960s (Hussein, 2000), along with traditional hives, though less commonly in the south-west (Alqarni et al., 2011). The Langstroth hive is a vertically modular hive which consists of Langstroth frames (Figure 3), movable frames to contain the honeycombs made by the bees. Beekeepers in Saudi Arabia are now told to reduce the number of frames used (Al-Ghamdi & Adgaba, 2015a), mainly because of the small colony size, which may be unable to fill even the base of such hives and is a consequence of adaptation of native bees to a shorter flowering season

and a longer period of dearth (Al-Ghamdi & Adgaba, 2015a). The great majority of traditional beekeepers keep the local bees *A. m. jemenitica;* Al-Ghamdi et al. (2017b) found 89.9% of traditional operations studied involved local bees only compared to only 36.5% of operations using box hives.

Figure 3. Left: A frame from a Langstroth hive; Right: Langstroth hives on pallets. Source: Left: from https://en.wikipedia.org/wiki/Langstroth_hive#/media/File:Langstroth_Frames.jpg, image created by Luc Viatour / https://Lucnix.be ; Right: from https://en.wikipedia.org/wiki/Apiary#/media/File:Apiary_259F.JPG, image created by Wikipedia User:Pollinator, both unaltered images, licensed under CC BY-SA 3.0.

Traditional apiaries consist of about 30 bee hives stacked together (Al-Ghamdi & Adgaba, 2015a), or even up to 1,000 (Robinson & Abrol, 2000), facilitating efficient shelter and management but also possible faster spread of disease and competition for forage. Sites which bees are migrated to may contain many more hives. Both fixed and movable stacks are available for traditional hives. In the case of box hives, bees are kept in permanent apiaries (Al-Ghamdi & Adgaba, 2015a). There are a limited number of practices in KSA used to manage honey bees kept in traditional hives. The inner volume of the hive may be modified by the beekeeper to reduce the space for the colony, depending on the season, due to variation of the colony sizes (Al-Ghamdi & Adgaba, 2015a). Swarming is uncontrolled in traditional hives (Alqarni et al., 2011). To fill hives, sometimes beekeepers catch swarms from trees. Also, bait hives are used to lure the swarms. Supplementary

feeding with sugar syrup is common, as is provision of water, and covering log hives with insulation against the summer heat (Al-Ghamdi & Adgaba, 2015a).

5. Foraging and forage sources in KSA

Foraging and environmental conditions in general: Strong adult forage workers seek out, carry and store food. Forager bees collect water, nectar, pollen, resins, and wax (Dimou & Thrasyvoulou, 2007), and the workers' foraging skills increase with age (Dukas & Visscher, 1994). Scout or persistent forager bees search for the best food sources and inform the reticent foragers about a food source through their waggle dance (Wagner et al., 2013). The foraging task is influenced by many factors, such as night sleep of forager bees (Beyaert, Greggers, & Menzel, 2012), group and individual decisions of forager bees, queen presence and status (virgin or mated) (Abou-Shaara, 2014), colony strength and brood rearing (Abou-Shaara, 2014; Amdam et al., 2009), as well as environmental conditions including the availability of plants. Foraging distance ranges from 45 metres to 5,983 metres (Higginson et al., 2011). While honey bees forage for nectar and pollen from suitable plants, as their foods (Adgaba et al., 2017a) and pollen and nectar are the main sources of carbohydrates, proteins, fats, minerals, vitamins, and water, necessary for a colony to develop (Loper & Berdel, 1980), the percentage of flowering plant species in the world which honey bees use as food sources is very low, only 16% (Crane, 1990).

Forage sources within KSA: Within Saudi Arabia there is a diverse range of flowers and plants, even in areas where there is little rain and long dry spells. There are about 2,200 flowering plants in Saudi Arabia (Chaudhary, 2000; Collenette, 1999) which contribute much of the pollen and nectar. Research has also shown that Saudi Arabia has substantial growth of vines and shrubbery, which are critical for honey production, as well as a wide range of both annual and perennial herbs which also benefit honey production (Al-Ghamdi & Adgaba, 2015b). Due to their ability to flourish in the Saudi conditions, a variety of plants have adapted well and grow quickly, flowering abundantly. This means that the lowlands and plains of Saudi Arabia are vibrant after short rainfalls, as plants and flowers flourish quickly.

Plants from the families *Fabaceae*, *Lamiaceae* and *Rhamnaceae* provide excellent, widespread, nectar sources for honey bees in Saudi Arabia. Very good sources of honey are obtained from

some species of the genus *Acacia*, *Lamiaceae* (*Lavandula*), and *Ziziphus* (Adgaba et al., 2017a). *Acacia* are drought-tolerant and many species can be found in the deserts of Africa, the Middle East and much of the Arabian Peninsula (Wickens, 1995). The main species for honey in Saudi Arabia include *Acacia gerrardii* Benth*., Acacia johnwoodii* Boulos, *Acacia ehrenbergiana* Hayne*,* and *Acacia origena* Hunde (Adgaba et al., 2017a) and *Acacia tortilis* (Hussein, 2000).

Saudi Arabia is believed to be the source and main geographical area of diversity of the *Lamiaceae* plant family (Miller, 1985; Wickens, Field, & Goodin, 2012). Seventy six species of *Lamiaceae* can be found there (Raja, 2012; Saqib et al., 2014; Venkateshappa & Sreenath, 2013), among which some are considered as good sources of honey (Tsigouri & Passaloglou-Katrali, 2000). *Lavandula dentata, L. coronopifolia* Poir, *L stricta* Del., and *L. pubescens* Decne. are amongst those which grow naturally in Saudi Arabia (Rahman et al., 2004; Tsigouri & Passaloglou-Katrali, 2000). *Lavandula dentata* and *L. pubescens* grow in the mountainous regions of Taif, Asir and Albaha (Adgaba et al., 2017a), where much of the beekeeping is found.

Plants from the family *Rhamnaceae* (buckthorn) and genus *Ziziphus* are also important forage sources in KSA (Abalaka, Daniyan, & Mann, 2010; Cherry, 1985). Most of the species of *Ziziphus* are well adapted to low rainfall and extreme heat (Orwa et al., 2009). Honey from these shrubs and trees is one of the most expensive in Saudi Arabia, because people like to buy honey that is locally produced and of known origin (Adgaba et al., 2014). Four *Ziziphus* species are widely available in Saudi Arabia, which are *Ziziphus glabrate* Heyne, *Ziziphus mucronata* Willd., *Z. nummularia* and *Z. spina-christi* (Adgaba et al., 2017a).

Foraging activity in KSA: Honey bee foraging in general is known to occur at different times of day, beginning early in the morning and finishing in the evening. Various studies have examined this and identify foraging beginning as early as 6.17a.m., whereas in the desert foragers are believed to leave their colonies at 8a.m.. There is disagreement about when most foraging and pollen collection takes place, which is likely to be dependent on the region and availability of flowers (Joshi & Joshi, 2010; Abou-Shaara, 2014; Reyes-Carrillo et al., 2007). In Saudi Arabia, Taha et al. (2016) found that foraging for nectar and pollen on alfafa flowers, a major source of forage, peaked between the hours of 0800 to 0900, and between 1700 and 1800. There was more pollen gathering from 0800-0900.

Establishing effective foraging systems for bees is critical because there are periods of the year when the natural forage in Saudi Arabia is inadequate and therefore it is necessary that plants which are suitable for bees are identified and planted (Al-Ghamdi, 2007). Awareness of when and where forage is available is essential for honey bee colony survival, as colonies are dependent on foraging bees. Iqbal et al. (2019) compared olfactory response of indigenous *A. m. jemenitica* honey bees with those of exotic imported bees (*A. m. carnica* and *A. m. ligustica*) and identified that indigenous bees, although tolerant to the heat in central Saudi Arabia, showed slower learning and poorer memory retention than the exotic bees. They suggested that *A. m. jemenitica* may use more energy to survive heat stress and their greater foraging activity than the exotic bees, impairing their cognitive performance.

Foraging in Saudi Arabia is hampered by the hot, dry climate, which means that there are months of the year in which there is a lack of bee flora. The normal way adopted in Saudi Arabia to tackle this is through colonies being fed with sugar syrup and pollen substitutes. The difficulty with such an approach is that there is no artificial substitute equivalent to pollen and nectar, hence the need for beekeepers to be aware of the sources where pollen and nectar can be found throughout the year. Such information means that beekeepers can manage their colonies better, and migrate them to other areas of the country when there is a scarcity in the area where they mostly keep their colonies. Having this information means that beekeepers can take steps to ensure the strength of their colonies, which in turn will ensure that they continue to yield a high level of honey (Taha, 2015) and also help to minimise colony losses. This explains the extensive practice of migration of colonies in KSA.

Taha (2015) conducted the first study to identify the main sources of pollen and nectar in the Al-Ahsa province in the east of Saudi Arabia, as well as those months where there was a scarcity of forage. *Medicago sativa* (alfalfa)*, Ziziphus* spp. and *Citrus* spp. were found to be the main sources of nectar. Several main pollen sources were identified, with *Cucurbita pepo* as most abundant, then *Phoenix dactylifera, Helianthus annuus, M. sativa* and *Brassica napus,* in that order. In a study of various insect pollinators in Saudi Arabia, Taha et al. (2016) found that alfalfa was mostly pollinated by honey bees, and dwarf honey bees (*A. florea* F.) in particular were the most active. Taha (2015) recommended that beekeepers in this area of Saudi Arabia would benefit from moving their colonies in February and March when *Citrus* spp. blooms, in order to continue to have a favourable honey yield and reduce the need for supplementary feeding. Similarly, colonies could

be moved in the period of May to June to benefit from the blooming of *M. sativa*, and also in September to October to benefit from *Ziziphus* spp. The study also identified those plants whose pollen could be trapped, and the periods of the year when they are in bloom.

Awad et al. (2017) compared *Apis mellifera jemenitica,* native to Saudi Arabia*,* with the (European) Carniolan subspecies in terms of performance in sub-tropical conditions, as the imported *A. m. carnica* is native to conditions with an abundance of nectar-rich flora. The study was conducted in Rawdhat-Khoraim, a desert location in central Saudi Arabia. Only three species of flowering plants exist there, the most abundant being Talh trees (*Acacia gerrardii*), which bloom from May to August. The study found that the presence of Talh, which is rich in nectar, meant that honey bee colonies could flourish, even in the harsh summer months. This meant that colonies were able to produce brood and store food, with the indigenous species faring better than the Carniolan colonies. Although both subspecies produced a similar honey yield, the native bees built stronger colonies and so were more able to adapt to the conditions encountered in the region. The native colonies did consume their stored honey quickly. Awad et al. (2017) recommend that beekeepers in Saudi Arabia consider the importance of Tahl forage and carefully choose subspecies of bees which will be able to flourish most in the hot, dry and windy summer conditions which are faced in much of Saudi Arabia.

In a similar study, but with a focus on pollen, Alqarni (2020) compared foraging activity and pollen-collecting of *A. m. jemenitica* and *A. m. carnica,* during the blooming of *Acacia* trees in Rawdhat-Khoraim oasis, which produce most flowers in mid-summer at the hottest time of year, in harsh weather conditions. The study found that *A. m. jemenitica* were significantly more active in foraging, used more foraging trips for pollen collection and collected significantly more pollen than *A. m. carnica.* A general conclusion was that the presence of the nectar-rich *Acacia gerrardii* could improve foraging rates of honey bee colonies in hot, dry and windy conditions.

6. Challenges of beekeeping in KSA

Major challenges to successful beekeeping in Saudi Arabia include honey bee diseases and parasites, as elsewhere in the world. A wide range of pests and predators of honey bees is also found in Saudi Arabia, including many species of wasps, hornets, wax moths, ants, beetles, reptiles and bee-eating birds (Robinson & Abrol, 2000; Al-Ghamdi et al., 2016). Adgaba et al. (2014)

mention bee-eating birds and wasps as the main predators, both of which are difficult to control against. The occurrence and distribution of honey bee pests and diseases in Saudi Arabia were reviewed by Al-Ghamdi & Adgaba (2015b), who reported infestation of honey bee colonies in different places by *Nosema*, *Amoeba*, chalkbrood, American Foul Brood, European Foul Brood, *Bacillus alvei*, black queen-cell virus, acute paralysis virus, chronic paralysis virus, *Varroa destructor* and *Braula coeca*, at different rates of infestation (1%-30%). Of these, *V. destructor* had important negative economic consequences for Saudi Arabian honey production, because of both its wide distribution and the levels of infestation (Alattal & Al-Ghamdi, 2015). The occurrence and distribution of many honey bee diseases in Saudi Arabia were associated with the annual large-scale importation of package bees from other countries, owing to high colony loss rates, and the extensive practice of colony migration (Al-Ghamdi & Adgaba, 2015b).

Severe weather poses a major threat to honey bees and beekeeping. Low but erratic rainfall, as well as recurrent droughts, strongly affect bee forage conditions. Al-Ghamdi and Adgaba (2015b) reported that long dry periods were associated with shortage of forage, contributing to the annual loss of bee colonies in Saudi Arabia, as lack of forage is critical (Adgaba et al., 2017b). They also reported that in central Saudi Arabia the temperature can exceed 40°C in June, July and August. During these months, relative humidity falls below 20%. Both high temperatures and low humidity are very detrimental to brood-rearing and colony survival. During these months, many colonies, particularly imported races, die due to the unsuitable extreme weather conditions in central Saudi Arabia.

Al-Ghamdi et al. (2017a) identified benefits of colonies which consisted of the local bee, *Apis mellifera jemenitica,* rather than imported bees (hybrid *A. m. carnica* / *A. m. lamarckii* (native to Egypt)) in a study carried out in lowland and upland areas of Al-Baha, south-western Saudi Arabia. In lower non-mountainous areas, with relatively higher temperatures and low rainfall, such colonies maintained significantly larger brood and larger populations of adult bees, therefore were stronger, and moreover they produced more honey than the imported bees. In both areas, colonies of the indigenous species stored an average of three times more pollen. In 7 out of 12 months (October to April), the local bees produced more queen cells than the exotic hybrids, indicating preparation for swarming, however the hybrid bees produced more in June-August. The annual survival rate of the indigenous species was almost twice as good as for non-indigenous species. The authors suggest that the better results achieved by the native species may be due to the fact

that they were better adapted to the lack of resources and the harsh conditions which exist in Saudi Arabia, illustrated by the sharper fluctuations in the brood and adult bee populations in the native bees. Imported colonies, by contrast, struggled to adapt to the conditions. Despite the better performance of *A. m. jemenitica* in the particular conditions faced in Saudi Arabia, there is a major issue within Saudi Arabia that availability of this subspecies is not sufficient to meet demand for honey and therefore the beekeeping industry depends on the use of colonies imported from other countries. However this is not without challenges.

Ali et al. (2017) studied haemolymph osmotic concentrations in *A. m. jemenitica, A. m. carnica* from Egypt and *A. m. ligustica* from Jordan, in spring and summer in central Saudi Arabia, and found that in both spring and summer *A. m. ligustica* had significantly higher osmotic concentration 25 days after emergence of honey bee workers than either *A. m. jemenitica or A. m. carnica*, with a similar significant difference found at day 1 in summer. This was interpreted as the Italian bees being less able to adapt to the conditions and suffering greater heat stress. Ali et al. (2019) found evidence of differences in the hypopharyngeal glands between Yemeni bees and imported Carniolan and Italian bees in summer and in winter, also suggesting the greater adaptation of *A. m. jemenitica* to the environmental conditions of Saudi Arabia. In a comparison of expression of heat shock proteins in honey bee haemolymph at 40°C and 45°C in *A. m. jemenitica, A. m. carnica* and *A. m. ligustica*, Alqarni et al. (2019) found least evidence of heat stress amongst the native bees, *A. m. jemenitica,* and most among *A. m. ligustica,* again indicating the greater suitability of *A. m. jemenitica* for the heat of the climate of Saudi Arabia.

Another challenge is the reputed low honey yield of indigenous honey bee colonies, insufficient to satisfy demand. For example, in a study in Asir region in south-west Saudi Arabia, Alqarni et al. (2014) found that Carniolan bees yielded more honey than Yemeni bees; while native bees produced more brood and stored more pollen, they also consumed more stored honey. Therefore *A. m. carnica* and *A. m. ligustica* are imported from Egypt and Australia, as races yielding more honey per colony for harvesting, but which are also relatively easy to handle. The average price of imported package bees has been cited as USD 30-40 per colony (Al-Ghamdi & Adgaba, 2015b), cheaper than native bees at USD 100-120 per colony (Al-Ghamdi et al., 2017a). However, more than 70% of imported colonies die soon after honey harvest, which may be due to their inability to withstand the long, dry and hot seasonal conditions. Alattal and Al-Ghamdi (2015) cite colony loss rates of 46% for *A. m. jemenitica*, 92% for *A. m. carnica* and 84% for *A. m. ligustica*, in a

study of honey bee survival in Riyadh (desert conditions) and Al-Baha (semi-arid conditions) over a two-year period. Most losses (76%) occurred in the summer months of August and September, in temperatures of 38°C to 46°C. Most of the losses of the exotic bees were in the first year. Therefore beekeepers keeping these high-yielding imported races of honey bee must often start from new package bees each year (Al-Ghamdi & Adgaba, 2015b). The findings of Al-Ghamdi et al. (2017a) in relation to honey yield of native bees in lowland apiaries indicate that the large-scale importation of honey bees may not be justified and that efforts to increase availability of local bees should be increased. However, Abou-Shaara et al. (2013) suggest that both non-native and native bees may perform and survive better if provided with a suitable type of hive to protect them from the extreme environmental conditions in summer in Saudi Arabia. They compared use of four modified hive types with *A. m. jemenitica* and *A. m. carnica*, and concluded that Carniolan bees fared best with insulated cover boxes for their hive, while the Yemeni bees did best with thermoregulatory hives which controlled temperature and relative humidity. Colony strength, performance and activity were monitored. Therefore a suitable choice of hive may make non-native bee operations more successful and reduce loss of colonies, or alternatively enhance colony performance for native bees. The Carniolan bees were found to store more honey whereas the Yemeni bees stored more pollen.

7. Structure and organisation of beekeeping in KSA

The Beekeepers Cooperative Association (BCA; http:// bca.saudibi.com/) plays an important role in achieving the goal of greatly expanding the beekeeping industry in Saudi Arabia, which is desirable owing to the demand for honey, as well as the opportunities to generate income. Established in 2008 in the Al-Baha region, the BCA supports individuals, private sectors and government organisations with an interest in the beekeeping industry. Its specialists provide technical support, help in decision -making and in increasing coordination and integration among beekeepers.

The BCA acts in various ways for the welfare of the beekeeping industry. It tests honey using several quality standards (Hussein, 2000) and has a vital role in marketing honey around Saudi Arabia. It supplies high quality queen bees, hives, modern tools, pesticides and insecticides at a reasonable price. It also supplies advice to the beekeepers. It organises lectures, symposiums and workshops about honey bees and bee products.

Saudi Arabia is a member of the Arab Beekeepers Union, established in 1994 to improve the practice of beekeeping throughout the Arab world (http://abu.saudibi.com/). Its objective is to coordinate exchange of information and experience among Arab countries, as well as to support scientific research. It also helps in the exchange of bee products among the Arab countries.

Due to its popularity in the Saudi population, beekeeping may be a niche in Saudi farming but it is a sizeable one and one that the government is keen on supporting through subsidies, grants and loans (Al-Ghamdi et al., 2014). In Saudi Arabia, the organisation of beekeeping is supported by the government in different departments. The Ministry of Agriculture provides technical support and services to beekeepers, whereas the Ministry of Social Affairs provides help to both individual beekeepers and beekeeper associations to help them develop their beekeeping as a business providing a source of income.

Also, within universities there is support for the beekeeping industry. The Food Science and Agriculture Faculty of the King Saud University has a Bee Research Unit which contributes to the development of beekeeping in Saudi Arabia through research into bee biology, bee botany, bee diseases, and bee husbandry techniques (Al-Ghamdi & Adgaba, 2015b). Such assistance is required as there is high demand for honey in Saudi Arabia and there are relatively few producers.

Saudi Arabia is affected by ecological factors which may contribute to the losses of colonies. In particular there are very high temperatures in the summer which can result in drought. Furthermore mite infestation can reduce colonies, as can widespread, improper uses of pesticides. Another factor is that some colonies are mismanaged (Al-Ghamdi et al., 2016). Saudi beekeepers are inclined to import honey bee packages in order to establish a colony, however this can be to the detriment of indigenous species, which results in low production and significant losses (Alattal & Al-Ghamdi, 2015).

It is therefore important that there is government and academic support for the industry, to allow new techniques to be introduced which will facilitate beekeepers to tackle colony losses and increase honey production to meet local demands, which will result in less importation of honey.

Although there are many beekeepers in Saudi Arabia, very little is known about those who keep the bees or their socio-economic situation. Nor is there much known about the honey production systems (Adgaba et al., 2014; Al-Ghamdi et al., 2014). Beekeeper Associations exist at regional levels but they lack national co-ordination, and this is one way in which intervention and support by government agencies may be beneficial.

8. Summary and Conclusions

Saudi Arabia has an attractive honey market with high consumer demand for honey. Honey is widely used throughout Saudi Arabia, as a medicine and a sweetening agent, and in the holy month of Ramadan for evening desserts. The medicinal property of honey (Al-Ghamdi & Ansari, 2021; Owayss et al., 2020) is given a higher value by Saudi Arabians than its nutritional properties (Al-Ghamdi & Adgaba, 2015b). Locally produced honey is sold at a higher price than imported honey (Robinson & Abrol, 2000; Adgaba et al., 2014), although it can only meet about a quarter of the demand, therefore there is great potential to expand honey production. The deeply-rooted importance of honey in Saudi Arabian society and the high price of its local honey leads many people to take up beekeeping as a full-time business. Honey is also an important source of additional income for rural people to help them improve from a relatively low standard of living (Al-Ghamdi & Adgaba, 2015b).

Acacia and *Ziziphus* are particularly important sources of forage for honey production, notably *Acacia gerrardii* Benth. (Tahl trees) and *Ziziphus spina-christi* L. (Sidr trees). Owayss et al. (2020) found Tahl honey to have greater antimicrobial properties than Sidr honey, however both showed valuable antibacterial activity. Honey production occurs in most parts of the country, but the majority of practice takes place in the mountain areas in the south-western mountainous region of the country; more than 70% of the bee colonies are located in this area, as the environmental conditions are more suitable there.

Traditional hives are still used by many beekeepers in Saudi Arabia, for their insulating properties and because local honey bees are better suited to this type of hive than to box hives, but perhaps more telling with regard to beekeeping in Saudi Arabia, these types of beehive and traditional practices are popular because not much equipment is required and the cost of these hives is lower than of box hives (Al-Ghamdi & Adgaba, 2015a). While for various reasons the majority of beekeepers do use the traditional hives made from local materials, modern box hives are also used. More extensive use of box hives could make the beekeeping more productive and more profitable even if the initial costs are higher; Al-Ghamdi et al. (2017b) found that box hives were 72% more productive than traditional hives in terms of honey yield per colony, and that beekeeping operations using box hives were on average more than twice as profitable per colony. There was also a focus on selling honey rather than other products of the hive, and diversification could enhance profitability. The country has strong institutional support to improve the beekeeping

sector. Government organisations such as the Ministry of Agriculture and Ministry of Social Affairs are providing technical support to beekeepers (Al-Ghamdi & Adgaba, 2015b).

The floral diversity and abundance are advantages for honey bees and beekeepers in the harsh environmental conditions of Saudi Arabia. The native honey bee, *A. m. jemenitica*, is well adapted to those conditions, yet many beekeepers import bees. Many beekeepers also migrate their bees to take advantage of more favourable climate and foraging.

Despite these positive conditions for beekeeping in the country, some aspects should be improved for the betterment of the Saudi beekeeping industry. There is a need for more research regarding foraging activity of the different honey bee races kept, nectar and pollen sources of honey bees, and ways to manage bee colonies successfully in the long dry season, especially for imported bees which are good honey producers but are not adapted to the local conditions and may need to be replaced annually. Colony loss rates even for native bees can be high. Extensive biological, ecological, and systematic study will help to inform the government and beekeeping organisations, to improve the beekeeping industry. Communicating advice to beekeepers on suitable hive types may be beneficial. Moreover, new studies will add to the limited available data and publications about the strength of the honey bee population itself in Saudi Arabia, beekeeping practices and particular difficulties faced by beekeepers.

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