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ORIGINAL ARTICLE

New approach for determination of an optimum honeybee colony's carrying capacity based on productivity and nectar secretion potential of bee forage species

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Abstract The present study was carried out to determine an optimum honeybee colony's carrying capacity of selected valleys dominated by *Ziziphus spina-christi* and *Acacia tortilis* in the Al-Baha region, Kingdom of Saudi Arabia. The study was conducted based on the assessment of the number of colonies kept, their productivities and the existing productive bee forage resources in the target valleys with its economic implication. In the existing beekeeping practice, the average number of managed honeybee colonies introduced per square kilometer was 530 and 317 during the flowering period of *Z. spina-christi* and *A. tortilis*, respectively. Furthermore, the overall ratios of productive bee forage plants to the number of honeybee colonies introduced were 0.55 and 11.12 to *Ziziphus* trees and *A. tortilis* shrubs respectively. In the existing situation the average honey production potential of 5.21 and 0.34 kg was recorded per *Ziziphus* and *A. tortilis* plants per flowering season, respectively. The present study, revealed that the number of honeybee colonies introduced in relation to the existing bee forage potential was extremely overcrowding which is beyond the carrying capacity of bee forage resources in selected valleys and it has been observed to affect the productivities and subsequent profitability of beekeeping. The study infers that, by keeping the optimum honeybee colony's carrying capacity of valleys (88 traditional hives/km^2 or 54 Langstroth hives/km^2

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in *Ziziphus* field and 72 traditional hives/km^2 or 44 Langstroth hives/km^2 in *A. tortilis* field), profitability of beekeeping can be boosted up to 130.39% and 207.98% during *Z. spina-christi* and *A. tortilis*, flowering seasons, respectively.

1. Introduction

Beekeeping is one of the most important economic activities for rural communities in Saudi Arabia, where approximately 5000 beekeepers maintain more than one million honeybee colonies and produce approximately 9000 tons of honey annually (Al-Ghamdi, 2007). Despite the rapid development of the subsector in the country, there are still many challenges and constraints facing the beekeeping industry (Al-Ghamdi and Nuru, 2013b). Among these, overcoming of the seasonal shortage of bee forage is one of the critical challenges to the development of this subsector.

In most cases, success in beekeeping depends on the availability of sufficient bee forage in terms of both quality and quantity of nectar and pollen grains. Hence, beekeeping is more dependent on the existing natural resource conditions of an area than any other livestock activities. In areas, where beekeeping is not suitable, other improved management skills and advanced technologies alone cannot make beekeeping successful. For this reason, availability of adequate bee forage is considered to be one of the most important elements in beekeeping industry. In many areas of the Kingdom, bees and beekeepers suffer from seasonal drought, which causes a shortage of bee forage (Al-Ghamdi and Nuru, 2013b; Alqarni et al., 2011). These conditions drive many beekeepers to move their colonies from one area to another in search of better nectar and/or pollen sources and to avoid severe weather conditions (Alqarni et al., 2011). However, this often leads to a concentration of a large number of bee colonies (owned by a single or multiple beekeepers) in limited areas, regardless of honeybee colony population density and the actual carrying capacity of the areas (Al-Ghamdi and Nuru, 2013a). Beekeepers concentrate on only some areas in search of a few particular species of plants that provide the most desired and expensive type of honey (Al-Ghamdi, 2005). In this regard, there is no directive to guide or determine the number of colonies to be placed per unit area, nor has it set out the minimum distances between two adjacent apiaries to minimize competition caused by the overlapping of foraging ranges and subsequent declines of productivity of colonies. As a result overcrowding and resource completion are very intense. Some studies suggested the minimum distance between two commercial apiaries to be 1.5–2 km (Hagler et al., 2011).

The occurrence of imbalances between the number of bee colonies and the important bee forage areas and the subsequent decline in productivity per colony has been well documented (Khanbash, 2001). Recent statistical data indicate, the number of bee colonies in the country has significantly increased some fourfold during the last decade, from 270,000 honeybee colonies in 1995 to more than one million in 2007 (Al-Ghamdi, 2007), while foraging areas have remained approximately unexpanded. On the other hand, a significant decline was reported in the average annual yield of honey per colony from 15 kg/colony in 1997 to about 8 kg/colony in 2007 (Al-Ghamdi, 2007). A recent study revealed the average annual yield of honey per colony declined to 3.7 kg/traditional hive and 6.6 kg/Langstroth hive in 2012 (Nuru et al., 2014), which is a great challenge for beekeeping industry. This decline in honey yield per colony can be attributed to many factors, the most important of which are scarcity of bee forage and overstocking honeybee colonies above the carrying capacity of available forage area (Al-Ghamdi, 2005). As a result, beekeepers are subjected to low financial returns from their honeybee colonies (Khanbash, 2001) and are unaware of how to increase the productivities of their colonies through optimizing the carrying capacity of bee forage areas. Therefore, assessing the optimum carrying capacity of major valleys is very crucial to guide beekeepers. Plant and flower density, nectar secretion potential and nectar sugar concentration were considered for determination of carrying capacity. In this study, the optimum carrying capacity was defined as the number of honeybee colonies on a given number of flowering plants per given area or places without negatively affecting honey production potential of individual colonies. The purposes of the present study were: (1) to assess the spatial and temporal distribution of selected bee forage plants and density of honey bee colonies along potential valleys, (2) to determine optimum colony carrying capacity of valleys based on yield potential and distribution of bee forage plants, and (3) to indicate the financial implications of bee colony overstocking in productivity and profitability of beekeeping.

2. Materials and methods

The study area is located in the Southwestern parts of Saudi Arabia, in some important valleys of the Al-Baha region. The study was conducted in two agro-ecologically different locations representing, midland and lowland areas. The midland valleys are those located at about 40 km North-East of Baljurashi Town (Barha-Magama, Wable and Kahla valleys), at a geographic location of 19°58″52′–20°06″41′N and 41°43’’52′–41°45’’18′E and at an altitudinal range of 1200–1700 m above sea level while the lowlands are located at 30–40 km Southwest of Buljurashi Town, at valleys Alkhaitan, Neera, Batat and Soqama having 19°43″18′–19°46″21′N and 41°38″52′–41°40″04′E geographical location, and altitudes ranging between 400 and 1000 m above sea level. In the region, *Ziziphus spina-christi* (Sidr) and *A. tortilis* (Sumra) are the major honey source plants that flower in different seasons, hence, were of major interest to address our objectives. The total land area of the study sites was about 25.2 km^2. Moreover the areas are intensively used by seasonal migratory beekeepers to place thousands of honeybee colonies for honey production during the flowering of the target bee forage species.