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Research article

Potential supply of floral resources to managed honey bees in natural mistbelt forests

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ABSTRACT

Honey bees play a vital role in the pollination of flowers in many agricultural systems, while providing honey through well managed beekeeping activities. Managed honey bees rely on the provision of pollen and nectar for their survival and productivity. Using data from field plot inventories in natural mistbelt forests, we (1) assessed the diversity and relative importance of honey bee plants, (2) explored the temporal availability of honey bee forage (nectar and pollen resources), and (3) elucidated how plant diversity (bee plant richness and overall plant richness) influenced the amount of forage available (production). A forage value index was defined on the basis of species-specific nectar and pollen values, and expected flowering period.

Up to 50% of the overall woody plant richness were found to be honey bee plant species, with varying flowering period. As expected, bee plant richness increased with overall plant richness. Interestingly, bee plants' flowering period was spread widely over a year, although the highest potential of forage supply was observed during the last quarter. We also found that only few honey bee plant species contributed 90 percent of the available forage. Surprisingly, overall plant richness did not significantly influence the bee forage value. Rather, bee plant species richness showed significant and greater effect. The results of this study suggest that mistbelt forests can contribute to increase the spatial and temporal availability of diverse floral resources for managed honey bees. Conservation efforts must be specifically oriented towards honey bee plant species in mistbelt forests to preserve and enhance their potential to help maintain honey bee colonies. The implications for forest management, beekeeping activities and pollination-based agriculture were discussed.

1. Introduction

Insect pollinators provide a vital service of pollination to flowering plants by foraging and transferring the pollen from one flower to another. Of all insects, bees are crucial pollinators, as they are fully dependent on floral resources (nectar and pollen) for forage provision (Buchmann and Nabhan, 1996; Shepherd et al., 2003). Bees feed on the floral resources of a wide variety of flowering plants, from natural and semi-natural habitats to surrounding agricultural landscapes (Ricketts et al., 2008), and contribute to the pollination of more than 66% of the world's crop species (Kremen et al., 2004).

With the increasing worldwide decline in insect pollinators (and thus reduction of pollination services) as a result of landscape fragmentation and modern agricultural practices (Potts et al., 2010; Whitehorn et al., 2012), honey bees (*Apis* spp.) have increasingly been managed for apiculture and provision of pollination services (de Lange et al., 2013). For instance, honey bee colonies can be managed and maintained by beekeepers in natural and semi-natural habitats that provide floral resources, and moved afterwards to other places (e.g. agricultural farms) when they are needed for pollination (Allsopp and Cherry, 2004; de Lange et al., 2013; Johannsmeier, 2005; Melin et al., 2014). Allsopp and Cherry (2004), and Johannsmeier (2005) documented the potential forage supply by many eucalypt species to honey bees in Western

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Cape province of South Africa, with some being excellent sources of high quality pollen. These authors argued that beekeepers rely on the flowering season of eucalypt plantations to maintain honey bee colonies, which will provide pollination service for deciduous fruits (e.g. apples, pears, plums and berries) in the following season. In addition, after the fruit pollination season, the majority of honey bee colonies used in the Western Cape for pollination services are maintained within eucalypt plantations (Allsopp and Cherry, 2004). However, because these plantations are fast growing monocultures with short rotation periods, and do not harbour high floral diversity, they provide forage resources of limited value (Allsopp and Cherry, 2004; de Lange et al., 2013). Conversely, protected natural forests usually support high floral diversity, and are primary sources of diversified floral resources for honey bees and other wild pollinators. Beekeepers report that the natural Fynbos in the Western Cape is a main forage source for honey bees from April to July (de Lange et al., 2013).

Limpopo (South Africa's northernmost province) is one of the most productive provinces, in terms of commercial timber (pine and eucalypt plantations) and agriculture (especially fruits and tea). The natural vegetation in Limpopo province is dominated by large and fragmented patches of mistbelt forests surrounded by plantations and agricultural areas (Mensah et al., 2016). Despite the high floral diversity in these mistbelt forests, there is little investigation and argument regarding their potential to provide floral and nesting resources for honey bees. As a corollary, very little is known about the suitability of mistbelt forests for beekeeping activities, as main or alternative sources of honey bee forage, in a typical forage-calendar year, similar to the Fynbos in the Western Cape province (de Lange et al., 2013; Melin et al., 2014).

The abundance and diversity of floral resources reflect a continuous supply of forage from different species and therefore, encourage honey bees to remain on site (Torné-Noguera et al., 2014). Yet, the availability of floral resources to honey bees in natural forests varies according to several factors such as distance from colonies (Jha and Kremen, 2013; Williams and Winfree, 2013), species-specific flowering phenology, tree size (Pardee and Philpott, 2014; Scaven and Rafferty, 2013), and spatial distribution of honey bee plants, which in turn determine the spatial and temporal distribution of flower and nesting resources (Torné-Noguera et al., 2014).

The abundance of floral resources at plant level is governed by whether (and how intensively) a honey bee plant flowers, i.e. the flowering area (Scaven and Rafferty, 2013), which however can be a poor predictor of visitation (Hülsmann et al., 2015). On trees, flowers and leaves both originate from buds, which are carried by twigs. Thus, the flowering area of a honey bee flowering plant will likely correlate with the amount of foliage, which in turn correlates with tree size and age (Otárola et al., 2013). Therefore, at plant community and forest stand scales, stand structural characteristics of bee plant species (stem density and stem basal area) will likely determine the potential amount of floral resources that attract honey bees from a distance (Hülsmann et al., 2015; Jha and Kremen, 2013; Pardee and Philpott, 2014).

At the plant community and forest stand scales, the diversity of floral resources would be governed by bee plant diversity because new bee plant species in flowers, added to the community, would likely contribute new species-specific phenological characteristics such flower production, pollen and nectar production. As pointed out by Blüthgen and Klein (2011), different plant species that flower together would contribute more to the production of floral resources than any of them alone, suggesting functional complementarity effects at the plant community level. Also, due to species-specific phenological/structural characteristics (longer flowering period, better quality of pollen and nectar, greater stand density and basal area), some bee plant species would likely contribute more to the overall forage production than other species.

In this paper, we aimed to quantify the availability of forage to honey bees in mistbelt forests, and how bee forage provision varied with honey bee plant diversity and overall plant diversity. We carried out field plot inventories in natural evergreen mistbelt forests in South Africa to (1) examine the diversity and relative importance of honey bee plants, (2) explore the temporal availability of honey bee forage (nectar and pollen resources), and (3) elucidate how plant diversity (bee plant richness and the overall plant richness) influences the bee forage production. For the first objective, we assessed the diversity of honey bee plants, and determined the most important honey bee forage plant species; we also asked whether plot level variation in all plant species richness was positively associated with variation in bee plant species richness. This association may not be straightforward, as rich plots (in terms of species) can contain very few bee plant species. Also, at the plot level, bee plant species represent a proportion of all plant species, with the strength of the association varying based on the relative abundance of honey bee plants across the study plots. In other words, no association would be expected if the distribution of honey bee plant richness across the studied plots showed early asymptotic trend. Second, we defined a forage value index (FVI, based on the species-specific nectar and pollen value, and the expected flowering period), and explored the temporal availability of the nectar and pollen forage value. Finally, we used the defined FVI as proxy for forage production, and modelled its relationships with plant diversity (plant richness and bee plant richness). We assumed that both overall plant richness and bee plant richness would positively influence the forage value.

2. Material and methods

2.1. Study area

The study was carried out in the Limpopo province located in the northern part of South Africa. The province is characterized by a succession of landscapes with highly varied topography, from zones of flat lowland plains to zones of high mountains, through mosaics of foothills and low mountains. The areas of low mountains and foothills are used for commercial and small scale subsistence farming, and commercial timber managed by forest companies. Many fragmented patches of natural forests and degraded woodlots non-suitable for forest plantations are also found in this area (Geldenhuys, 2002). Some crops fields (especially fruits) are established in the surrounding environment of natural and planted forests (eucalypt), and benefit from pollination services provided by wild pollinators and managed honey bees (Carvalheiro et al., 2010; Melin et al., 2014). The specific area selected for this study is the Woodbush-De Hoek natural forest (23°50′S, 30°03′E), considered as part of the Limpopo mistbelt forests (Mucina and Rutherford, 2006). The Woodbush-De Hoek forest covers a total area of about 6, 626 ha, and is one of the largest forest blocks of the Northern Mistbelt Forest group (Cooper, 1985; Geldenhuys, 2002). The woody flora is predominated by canopy species such as *Podocarpus latifolius*, *Combretum kraussii*, *Syzygium gerrardii* and understorey species such as *Peddiea africana*, *Oricia bachmannii*, *Kraussia floribunda* (Mucina and Rutherford, 2006).

2.2. Sampling for floristic data

The data used in this study was collected from a sample plot survey, based on a stratified random sampling design set in a 708 ha (hectare) forest block in the Woodbush De Hoek forest. The stratification of the research area was based on three classes of slope