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Plant Diversity and Honeybees' Foraging Preferences: An Implication for Honeybees' Conservation

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ABSTRACT

Identification of honeybees' preferred plant species is paramount for sustainable conservation, especially when honeybees are reported to be declining globally. The study assessed plant diversity in potential beekeeping areas in Northern Tanzania and determined the foraging preferences of honeybees across two rainy seasons of 2021/2022. We established quadrats of 5 x 5m (shrubs and forbs) nested with 1x1 m (grasses) at each of the four transects of 5 km distance to assess plant diversity and identify the most preferred plants in two study areas. The dominant plant families were *Poaceae, Malvaceae, Commelinaceae, Acanthaceae, Amaranthaceae, Polygonaceae, Asteraceae*, and *Lamiaceae*. There was a significant difference in plant diversity between short and long rain seasons in both study areas (t = 2.60, p = 0.01, and t = 2.27, p= 0.03). *Grewia bicolor, Terminalia brownii, Ziziphus mucronata, Combretum schumannii,* and *Cordia monoica* were the most visited plants by 2761, 2528, 1966, 1163, and 662 visits, respectively, during the short rain season, while *Acacia mellifera, Hoslundia opposita, Ocimum bacilicum* and *Acalypha fruticosa* were the most visited plant species by 1638, 788, 340, and 38 visits, respectively, during the long raing season. This study has highlighted important information on honeybees' foraging preferences and their diversity that shades a way for sustainable honeybees' conservation in the area and elsewhere. We recommend further identification and re-planting of honeybees' forages; awareness campaign to enlighten local people in beekeeping potential areas on the impact of activities that reduce plant diversity, negatively affecting honeybees.

***Key words**: Honeybees, Pollinators, Conservation, Foraging-Preference, And Plants.*

Introduction

Honeybees (*Apis mellifera*) are social insects of the Apis distributed worldwide. Honeybees live in colonies while pursuing different activities based on age and sex (Sajwani *et al.*, 2014). Globally, *Apis mellifera* has been very beneficial for its products and services to humans and ecosystems. Besides, they offer pollination services to angiosperm and most crop plants, which in turn ensure agricultural productivity and help to improve food security (Hung *et al.*, 2018). On the other hand, honeybees benefit from available plant resources such as nectar, pollen, and resin (Dukku, 2013). However, it has been reported that both wild and managed honeybee colonies are declining worldwide. Their decline negatively affects the beekeeping industry, ecosystem health, agricultural production, and livelihood improvement (Donkersley, 2019). Researchers have reported several factors contributing to the decline of honeybees' colonies (Donkersley, 2019; Goulson *et al.*, 2015). However, the impact of habitat degradation is reported as the leading and primary factor among many, triggered by anthropogenic activities and other environmental factors (Goulson *et al.*, 2015). The overall impact of these factors is the loss of plants and a decrease in their diversity, which consequently affects honeybees' forages and accelerates their decline.

Honeybees customarily depend and forage on various plant species, both flowering and non-flowering, around their home range (Aronne *et al.*, 2012; Requier and Leonhardt, 2020). However, to secure more resources, honeybees can travel to different distances depending on fodders availability, quality and quantity of fodders, flower morphology, and nutritional requirements of the colony by the meantime (De Vere *et al.*, 2017; Ghosh *et al.*, 2020). Moreover, regardless of foraging on a variety of plant species, honeybees show preferences and choices for certain plant species more than others in a particular landscape; this can be revealed by the foraging consistency and visitation rate of honeybees to particular plant species than other (Aronne *et al.*, 2012). Honeybees collect and use these plant-delivered resources as essential raw materials in food production and other hive products (De Vere *et al.*, 2017).

Regardless of this information on plants' diversity and honeybees' preferences towards available plants in an area, which are advantageous and the backbone of both honeybees' conservation and the beekeeping industry (Sajwani *et al.*, 2014; Urbanowicz *et al.*, 2020), little has been done so far, and there is still a knowledge gap at different beekeeping potential areas in Tanzania. This study, therefore, aimed to assess plant diversity in a honeybee's rich hotspot and potential bee keeping area in Northern Tanzania (Gidamis *et al.*, 2004) and to determine the foraging preferences of honeybees to available plants across two rainy seasons of 2021/2022. We hypothesized that there would be differences in plant species in study areas across the seasons; honeybees' forage preferences will also differ from one area to another across the seasons. We argue that to conserve honeybees and avoid their decline, we need to understand plant availability and abundance as well as honeybees' foraging preferences in areas they occupy, as this will aid in their conservation. This will, therefore, ensure a sustainable flow of benefits from the products and services they offer in agricultural production, ecosystem conservation, and livelihood improvement (Hung *et al.*, 2018).

Materials and Methods

Study site description

The study areas were located in Same district (Figure 1), Northern Tanzania in two wards of Kisiwani (-4.147426/37.9811853) and Vumari (-4.0235862/37.7219419), where beekeeping activities are conducted alongside the Mkomazi national park boundaries. The district is bordered to the north by Mwanga district, northeast by Kenya, southeast by Tanga region, and to the west by Manyara region. The areas experience annual rainfall ranging from 1000 to 2000 mm, divided into two seasons; a short rainy season occurs between November and January, and the long rainy season starts from February to May (Prins and Loth, 1988). The main economic activities in the areas are agricultural, where people are involved in both commercials by cultivating sisal and food production; besides agriculture, tourism is among other growing economic activities (Mwanyoka and Lopa, 2016). In addition, the Mkomazi national park and other protected areas, such as Pare Mountains, Chome, and Shengena forest reserves, prompt tourism activities in same district.

Assessment of plant diversity

Field observations assessed flowering plants' diversity and honeybees' foraging preferences during the short (November 2021-January 2022) and long (March-May 2022) rain seasons. As described previously by Ashton and Macintosh (2002), the transect method was used for plant diversity assessment with minor modifications. Two study areas with at least 30 occupied beehives were selected from two different areas about 40 km apart in Same district. In each area, we established two crosscutting transects of 5km each with beehives at the center; 20 points spaced at 0.5 km were established along two transects. At each point, two quadrats of 5m x 5m (shrubs and forbs) nested with 1m × 1 m (grasses) were systematically established on each side of the transect at 50m from the transect to make forty (40)

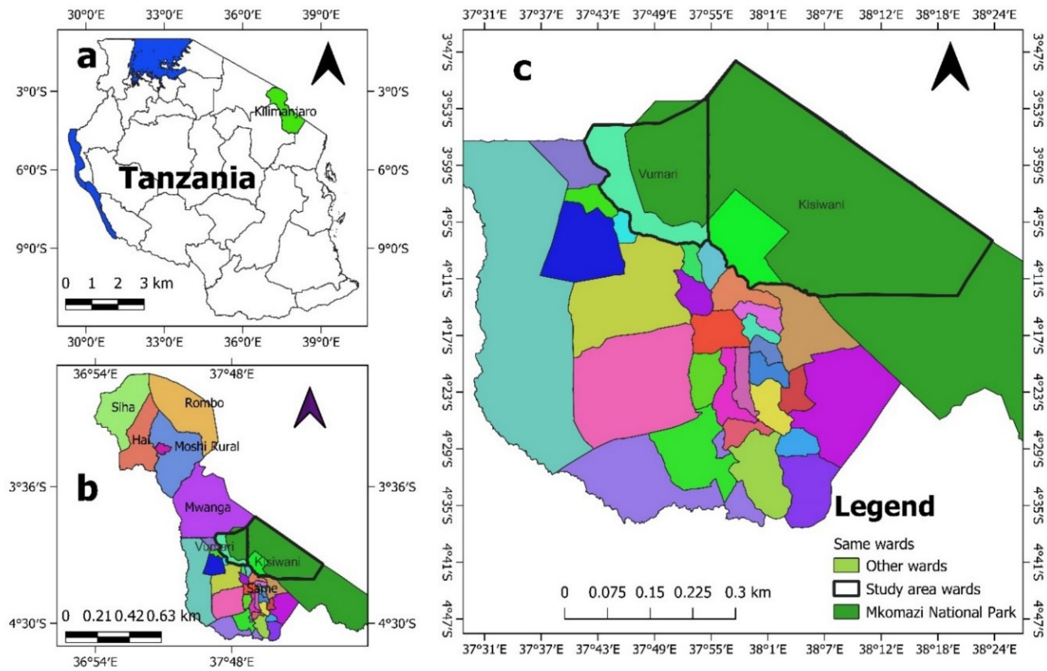


Fig. 1. The diagrammatical representation of the study areas, showing region (a), district (b), and wards (c) where the study was conducted in 2022.

5 x 5 m and forty (40) 1 x 1 m quadrats making a total of eighty (80) quadrats (N = 80) at each study area per season. All shrubs, forbs, and grasses in these quadrats were identified and counted.

Assessment of honeybees' foraging preference

The same quadrats established for plant diversity assessment were used for honeybees' foraging preference, considering plots with blooming plants during the study period. The observation was conducted from 8:00 am to 11:00 am and 4:00 pm to 6:00 pm. The observation involved recording the number of honeybee visits per flower per time (Arroyo *et al.*, 1985). Four people were involved in counting the number of bees' visits to different plant flowers in a quadrat, and the decision was consensus-oriented. The observation time at each quadrat of interest lasted for 5 minutes.

Statistical analysis

The Shannon-Wiener diversity index of plant species was calculated for each established quadrat for plant diversity. Shapiro–Wilk test for normality was performed on the generated indices. The independent sample t-test was used to determine if there was a significant difference in plant diversity between study areas within a particular season, while paired sample t-test was used to determine if there was a significant difference in plant diversity in the same study area during different rainy seasons. The statistical software used was R version 4.1.1(2021), with a significance level set at $\alpha < 0.05$.

Results and Discussion

General observations

In study area I, a total of 42 and 47 plant families were recorded in long and short rain seasons, respectively; in contrast, for study area II, a total of 52 and 41 plant families were recorded in the short and long rain seasons. During the short and long rain seasons, *Poaceae* was the most dominant plant family (Fig. 2). The dominance of this family could be attributed to several factors (Aboulaich *et al.*, 2013), including their ability to produce more pollen to survive in different environments regardless of the level of disturbances they could experience (Kikoti and Mligo, 2015; Peterson, 2013). Similar observations were reported elsewhere (Bao *et al*., 2018; Peterson, 2013). In Northern Tanzania, studies conducted by Barboni (2014) and Mseja *et al*. (2020). *Poaceae* is the most prominent plant family globally; it comprises many plant species with historical and evolutionary dominance characteristics in most landscapes, covering over 40% of all plant species globally (Strömberg, 2011). Members of the family *Poaceae* can grow and sustain minimum rainfall ranging from 50 mm per month (Prins and Loth, 1988); their allopathic mechanisms favor their growth and colonization (Favaretto *et al.*, 2018). Most plant species found in the family *Poaceae* are significant in the management of honeybees; for instance, they save as a source of food by providing nectar and pollen resources (Pangestika *et al.*, 2017). In addition, the family *Poaceae* plays a significant role in protecting and improving soil fertility by retaining soil moisture (Wang *et al.*, 2012) and preventing soil erosion (Fullen, 1998), which favors the survival of other plant species that are important for honeybees' survival.

We further observed other dominant families in different rain seasons, such as *Amaranthaceae*, *Malvaceae*, *Lamiaceae*, *Polygonaceae*, *Acanthaceae*, *Commelinaceae*, and *Asteraceae* (Fig. 2). Most of these plant families are essential in beekeeping as well, which can help conserve honeybees by providing food and shelter (Addi and Bareke, 2019; Akunne *et al*., 2016). For instance, the family *Asteraceae* saves the honeybees as a source of nectar and resin used in making honey and propolis (Çelemli and Sorkun, 2012). Therefore, it is essential for areas with such richness in plants that play a significant role in beekeeping to be conserved so that they can help ensure sustainable beekeeping for both honeybees' conservation and societal development through revenue

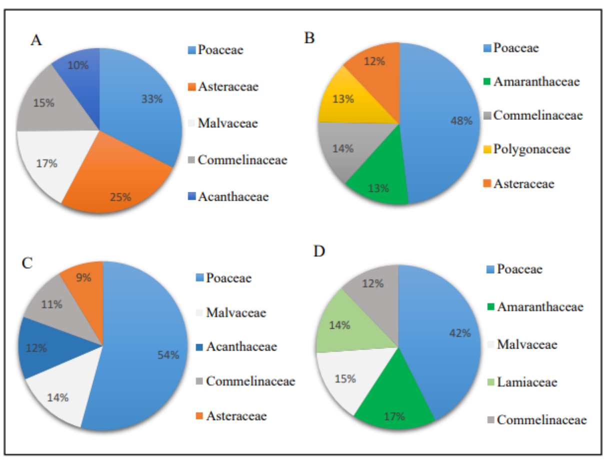


Fig. 2. The most dominant families in study area I (A) and study area II (B) during the short rain season and study area I (C) and study area II (D) during the long rain season of 2021/2022.

generated from honey and other beekeeping-related products.

Plant diversity

There were significant differences in plant diversity between the short and long rain seasons in both study areas (t = 2.60, p = 0.01, and t = 2.27 p = 0.03) (Table 1). These findings agreed with other studies that assessed plant diversity in different seasons (Hassler *et al*., 2010; Tonkin *et al*., 2017). This variation in plant diversity could be attributed to several factors, such as variations in the amount of rainfall and other environmental factors across these seasons (Hatfield and Prueger, 2015; Smith *et al*., 2016). Moreover, compared to a short rainy season, a long rain season is often characterized by having consistent precipitation that favors the growth and development of various plant species and their composition (Knapp *et al*., 2002). The higher plant diversity during the long rainy season favors the persistence of honeybees due to increased food resources. It provides honeybees with a broader selection of essential resources such as nectar, pollen, and resin (Sutter *et al*., 2017). The initiatives to increase plant diversity for sustainable honeybee conservation are in high demand globally, especially in this era of highly declining in both managed and wild bee colonies (Donkersley, 2019; Goulson *et al*., 2015). Decreased plant diversity in a landscape has been associated with several negative implications for honeybees and other potential pollinators' survival in an ecosystem (Mensah *et al*., 2017). Results from our study alert beekeepers in Northern Tanzania and elsewhere that the long rainy season is crucial in the beekeeping calendar as the season of the primary honey flow because of diverse plants, especially honeybee fodders bloom, compared to the short rain season.

Moreover, we further found similarities in plant diversity in the study areas within the same rain season for both the short and long rain (t = 0.47, p = 0.64 and t = 0.58, p = 0.57)(Table 1), the similar results were reported previously in other studies (de Maçaneiro *et al*., 2016; Jiang *et al*., 2007). This could be due to several factors; for instance, De Carvalho *et al.* (2014) reported that soil physical-chemical characteristics in certain areas could contribute to the similarity in plant diversity. In addition, the level of disturbances and conservation initiatives of areas determine plant species diversity (de Maçaneiro *et al*., 2016). Therefore, if different areas receive the

Table 1. Plant diversity between short and long rain seasons of 2021/2022 in study areas

	Study area I		Study area II	
	Mean	SE of the mean	Mean	SE of the mean
Short rain	1.96	0.07	1.92	0.06
Long rain	2.09	0.05	2.04	0.06
T-test	t = 2.60, p = 0.01		t = 2.27, p = 0.03	

*SE= Standard Error

same level of conservation, they will most likely have uniformity in plant diversity. Moreover, Jiang *et al*. (2007) and Vasconcelos *et al.* (2020) reported that the altitude of different areas, evolutionary lines, and genetic factors also have a countable impact on similarity or variation in plant species diversity across different areas. Having similar plant diversity across the landscape in the same season facilitates honeybees' easy adaptation to areas within a landscape, especially for migratory beekeeping, which in turn ensures continued production of honeybees' products for both revenue accruing and honeybees' conservation, as their survival depends on plants (Carreck *et al.*, 1997; Rodolfo and Irene, 2009)

Honeybees' flower visitation and foraging preference

In both rain seasons, we found some plant species highly preferred by honeybees over others. A total of 7,902 and 4,201 honeybees visitations was recorded during the short rain season of 2021/2022 in study area I and II (Table 2). *Grewia bicolor* and *Combretum schumannii* were the most visited plants, with 2761 and 1,163 visits, in study areas I and II, during the short rain season (Fig. 3(A) and (B)).

A total of 2,099 and 2,568 visits were recorded in study areas I and II, respectively, during the long rain season (Table 3). During the long rain season, the most visited plants in the study areas were *Acacia mellifera* and *Hoslundia opposita* (Fig. 3(C) and (D).

Honeybees' visitation preference for these plants is contributed by several factors, such as the number of flowers per plant (Akter *et al*., 2017) and floral color (Kevan, 1972; Miller *et al*., 2011). Flowers with bright and ultraviolent colors have been reported to attract more pollinators (Kevan, 1972; Miller *et al.*, 2011). Besides, flowers' colors enhance the visibility of honeybees and other plant depending insects (Whitney and Glover, 2007). In our study, we found that most of the identified plants as honeybees' preferred fodders had flowers with bright colors. In addition, the quality and quantity of nectar and other plant resources offered by plants to pollinators similarly contribute to increasing preference for particular plants, this feature of plant resources vary

Table 2. Honeybees' flower visitations during the short rain season of 2021/2022

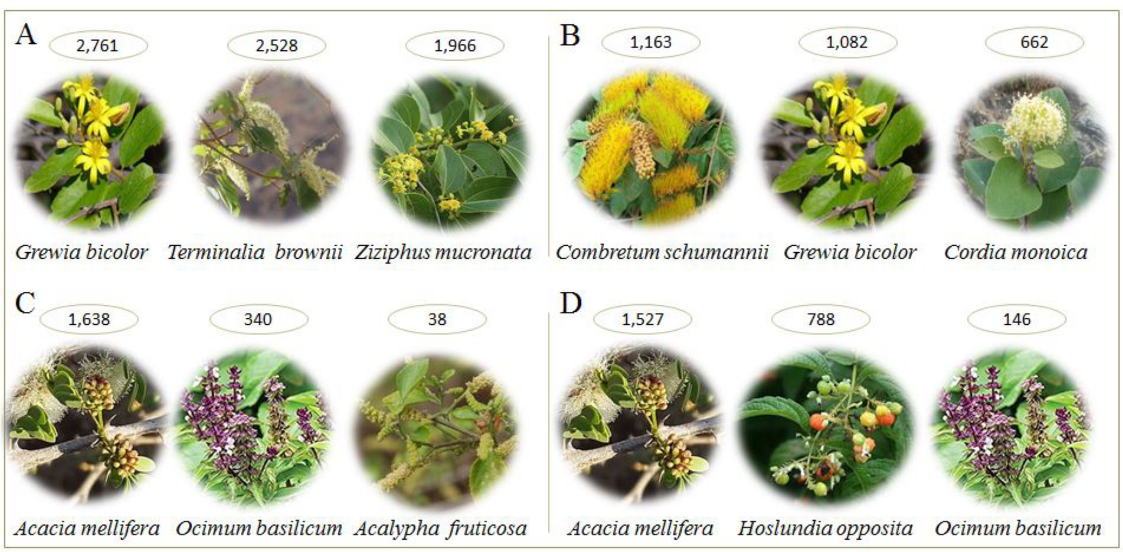
Area I		Area II	
Plant species	No. of visitations	Plant species	No. of visitations
Grewia bicolor	2761	*Combretum schumannii*	1163
Terminalia brownii	2528	*Grewia bicolor*	1082
Ziziphus mucronata	1966	*Cordia monoica*	662
Ocimum gratissimum	295	*Oxygonum sinuatum*	461
Aspilia mossambicensis	233	*Urochloa panicoides*	445
Oxygonum sinuatum	50	*Acacia nilotica*	118
Ocimum obovatum	30	*Clerodendrum spp*	89
Lantana camara	16	*Waltheria indica*	82
Commelina benghalensis	10	*Combretum hereroense*	39
Hypericum revolutum	4	*Justicia matammensis*	21
Eragrostis superba	3	*Brachiaria deflexa*	18
Justicia nyassana	3	*Justicia eranthemoides*	13
		Digera muricata	4
		Digitaria abyssinica	3
		Barleria eranthemoides	1

Table 3. Honeybees' flower visitations during the long rain season of 2021/2022

Area I		Area II	
Plant species	No. of visitations	Plant species	No. of visitations
Acacia mellifera	1638	*Acacia mellifera*	1527
Ocimum basilicum	340	*Hoslundia opposita*	788
Acalypha fruticosa	38	*Ocimum basilicum*	146
Heteropogon contortus	26	*Acacia nilotica*	77
Triumfetta rhomboidea	19	*Achyranthes aspera*	14
Vernonia galamensis	11	*Acalypha fruticosa*	7
Commelina benghalensis	11	*Indigofera brevicalyx*	5
Justicia matammensis	6	*Eragrostis superba*	3
Ocimum obovatum	3	*Triumfetta rhomboidea*	1
Panicum maximum	3		
Indigofera arrecta	3		
Gnidia eminii	1		

among plant species (Abrol, 2006; De Vere *et al.*, 2017). Most of the visited plants found in our study were also reported in other studies conducted to have adequate quantity and quality of nectar and pollen that attract honeybees and plant-depending insects, respectively (Adgaba *et al.*, 2017; Martins, 2004).

Moreover, the presence of amino acid (proline) in nectar triggers honeybees and other pollinators to visit and forage particular plants Carter *et al.* (2006), of which some of the identified plants as most honeybees' preferred plants reported by several studies to contain a large amount of proline-amino acid in their nectar. For instance, Elaloui *et al.* (2015) revealed the availability of high proline in the nectar content of *Acacia* species and *Ziziphus mucronata*. The large size of flowers and the architecture of identified plants contributed to an increase in foraging preference by honeybees, as Whitney and Glover (2007) reported the same as plants with large flowers or many congested small-sized flowers are more likely to be visited than others. The identified plants, especially from the family *Lamiaceae*, contain smell-producing volatile compounds that stimulate honeybees to visit them (Díaz-Maroto *et al.*, 2004; Pichersky and Gershenzon, 2002). These features determine honeybees' foraging preference and solve the tradeoff of which plant to visit, especially when most plants bloom simultaneously (Butler and Station, 1944). Our observations revealed that honey-



The numbers above a picture represent the total number of honeybees visiting per plant

Fig. 3. The most visited plant species in study area I (A) and study area II (B) during the short rain season and study area I (C) and study area II (D) during the long rain season of 2021/2022.

bees do not just visit plants with flowers but seek plants with preferred features and that they prefer certain plants over others, as previously reported by Aronne *et al.* (2012) and Hawkins *et al.* (2015).

Conservation Implication and Conclusion

Honeybees' existence and the sustainability of beekeeping industry depend much on a healthier and diversified ecosystem. The scarcity of preferred plant species in the study areas and other beekeeping potential areas compromises the existence and accelerates their decline. This necessitates establishing conservation initiatives and managing landscapes to ensure fodders' availability, which is crucial for the sustainable conservation of honeybees and the continued supply of their products and services. Therefore, more emphasis should be placed on further identification of the most preferred plants in different seasons in study areas and elsewhere. Besides, further emphasis should be taken on conservation initiatives such as re-planting honeybees' preferred plants in the study areas and elsewhere where beekeeping activities are conducted. Furthermore, we recommend an awareness campaign to enlighten local people on the impact of excessive conduction of activities such as charcoal burning and logging that reduces plant diversity in the area and thus negatively affects honeybees. The authorities should encourage and support people to engage in beekeeping activities for income generation and achieve sustainable honeybee conservation and a healthier ecosystem.

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Declaration of Conflicting Interests

The author(s) declared no conflicts of interest concerning this article's research, authorship, and publication.

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