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RESEARCH PAPER

Quantifying Nectar Secretion Capacity of *Dombeya torrida* (J. F. Gmel.) for Honey Production

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Abstract

The honey production potential of a honey plant is assessed based on the total floral nectar secretion capacity of the plant foraged by honeybees within a specific location. This study aimed to assess the honey production potential of *Dombeya torrida* plants by examining their nectar secretion dynamics. A group of flowers was enclosed with mesh bags a day before collecting nectar to measure the accumulated volume. Nectar volume, concentration, and ambient temperature were measured at hourly intervals. The data collected were analyzed using statistical methods including one-way ANOVA and linear regression. The average sugar content per flower per season was found to be 14.3 mg, with a range from 2.3 to 47 mg. Based on this, each *D. torrida* tree was estimated to secrete an average of 0.94 kg of sugar, with a range from 0.15 to 3.1 kg. Nectar volume and concentration varied throughout the day, with temperature significantly influencing nectar concentration. The study estimated that a single *D. torrida* tree could yield around 1.2 kg of honey per flowering season, with a range from 0.18 to 3.78 kg. Additionally, on a larger scale, *D. torrida* plants were projected to produce an average of 300 kilograms of honey per hectare, ranging from 45 kg to 945 kg. These findings suggest that *D. torrida* has considerable potential for honey production. Consequently, planting and conservation of this plant for sustainable honey production practices is recommended.

Introduction

Honeybee plants are species that produce nectar and pollen as food for honeybees. The amount and quality of nectar, which are primarily controlled by biotic and abiotic factors, determine how much each bee plant species contributes to the honey production (Adgaba et al., 2017). Additionally, not all bee plants are equally important for bee development and honey production (Bareke & Addi, 2022). There are only a few prominent honey source plants in each geographical area. It is crucial to classify these honeybee plants according to how important they are to the process of producing honey.

Based on the dynamics of nectar secretion (volume and sugar concentration), many authors have evaluated the potential for honey production for a small number of honeybee plants. For instance, studies have identified *Lavandula dentata*, and *L. pubescens* (Adgaba et al., 2015), *Antigonon leptopus* and *Thevetia peruviana* (Adjaloo et al., 2015), *Otostegia fruticosa* and *Ziziphus spina-christi* (Adgaba et al., 2017), *Coffea arabica* (Bareke et al., 2021), *Hygrophila auriculata* and *Salvia leucantha* (Bareke & Addi, 2022), and *Pavonia urens* (Bareke & Addi, 2024) as potential honeybee plants based on their nectar secretion dynamics and sugar concentration. To estimate the number of honeybee colonies that can be supported in a particular region without significantly affecting the honey production potential of individual colonies, it is crucial to determine the honey production potential of honeybee plants (Al-ghamdi et al., 2016).

Ethiopia provides favorable environmental conditions for a variety of bee flora resources to thrive. The honey production potential for several bee forage plants has not yet been investigated. This is also true for *Dombeya torrida*. In Ethiopia, this plant species is the main source of honey. In central and southwest Ethiopia, *Dombeya torrida* is well-known as a fast-growing plant that is a significant source of honey. The honey produced by the flowers of this plant is white and flavorful (Adi et al., 2014). *Dombeya torrida*, known for its fast growth and ability to reach the flowering stage within three years, is frequently used in home gardens and as agroforestry trees (Adi et al., 2014). However, studies to quantify the amount of honey that could be obtained from the nectar of *D. torrida* are non-existent. This study is focused on determining the nectar secretion patterns and the potential amount of honey that can be sourced from the nectar of *Dombeya torrida.*

Material and Methods

Nectar volume was measured using micropipette. Nectar concentration was measured using a digital refractometer, while temperature was measured using a thermometer.

Study sites

The study area was Chellia District, South west Shewa zone, Ethiopia (Figure 1).

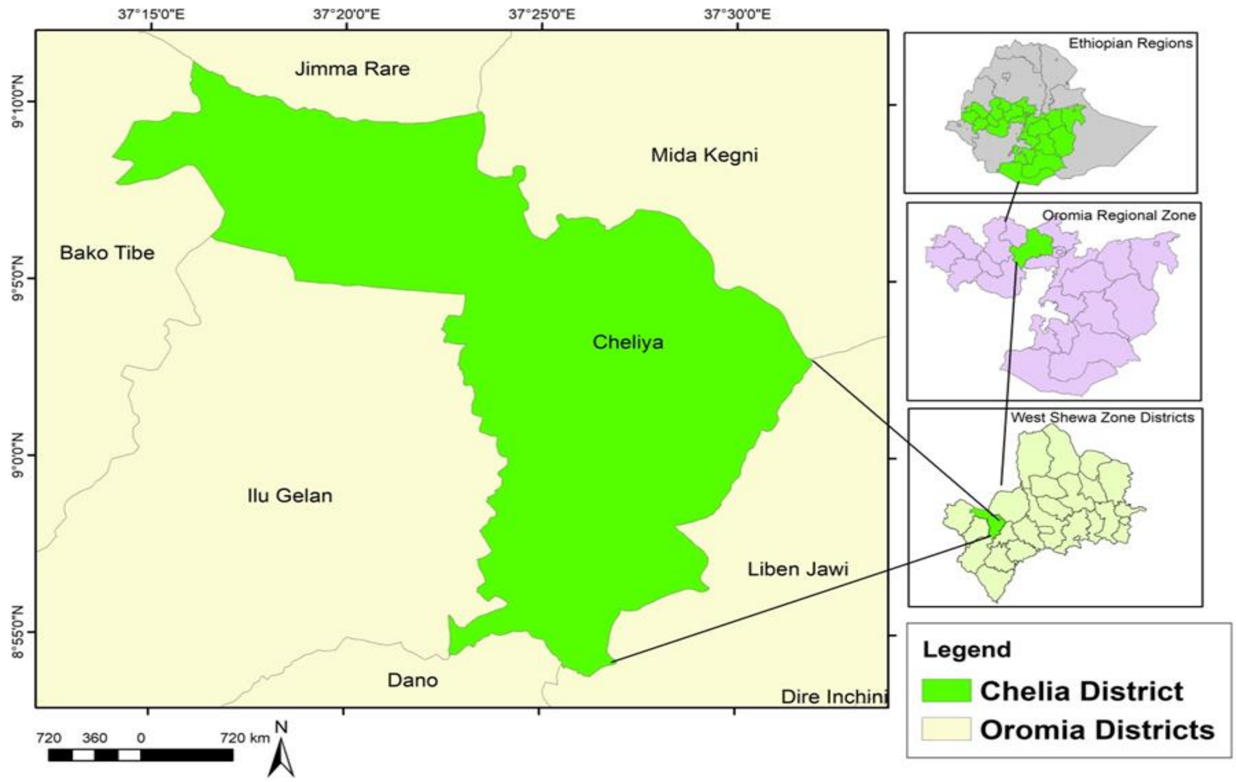

Figure 1. Map of the study area

Based on the accessibility and abundance of *D. torrida*, study locations were chosen. It was chosen because of its ecological adaption range and honeybee foraging intensity. The three-year experiment took place in Ethiopia's west Shewa Zone from 2019 to 2021.

Number of flowers per tree

To count the typical number of flower heads per plant, twenty four (24) prolific trees with enormous flowers were chosen at random (Bareke et al., 2020a). The main branches of trees were counted by taken three branches (Large, medium and small) from each plant was deliberately selected. The number of flower heads per inflorescence was counted from ten inflorescences per chosen branch (Bareke et al., 2020a). Finally, the number of flower heads per tree = (Total tree branches) x (average number of inflorescences per branch) x (average number of flower heads per inflorescence) determined following (Adgaba et al., 2017).

Figure 2. When nectar volume and nectar concentration measured in the field

Determining the length of the nectar secretion

Nectar secretion and flower opening and ending times were recorded. To identify the length of the nectar secretion, five distinct flowers were measured every day from the starting to ending of nectar secretion repeatedly (Bareke et al., 2020a).

Nectar volume and concentration measurement

One day before measuring nectar volume, five inflorescences were placed in different parts of the tree and covered with fine mesh bags (40 x 40 cm) to measure nectar (Farkas & Orosz-Kovács, 2003). Marks were made on randomly flowers from different inflorescence whorls (Wyatt et al., 1992) and for nectar measurement, a total of 24 individual plants were used for data collection. To measure nectar volume, fifty (50) flower heads per tree were randomly selected, and all nectar from flowers was collected at one interval during the day from the beginning of nectar release to the end. The average nectar yield per flower head was calculated from 900 flower heads. Using a digital refractometer, the nectar concentration as total soluble solids (TSS) was calculated instantly between the hours of 8:00 am and 12:00 pm.

Determination of sugar amount in nectar per flower

Nectar volume, nectar concentration and temperature were measured four times per day at intervals of 1 hour concurrently (Wyatt et al., 1992). The volume and concentration were used to determine the nectar's average sugar content. Most refractometer values are provided as milligrams of sugar per 100 mg of solution and are stated as sucrose equivalents. By converting the observed sucrose equivalent to grams per litre and multiplying this value by the nectar volume, they can be transformed into milligrams of sugar per flower (Bolten et al., 1979). The conversion of sucrose concentration to density was done using Pry-jones and Corbet (1991) equation and the amount of sugar was calculated using the (Dafni, 1992) equation.

The amount of sugar present in the nectar was determined based on nectar volume, concentration, and sucrose density. The sucrose density was estimated from the nectar concentration using the Prys-Jones and Corbet (1991) equation described as follows:

$$\rho = 0.003729/C + 0.0000178\ C^2 + 0.9988603$$

Where:

ρ: The estimate of sucrose density for a given value of C,

C: Nectar concentration (%) (Refractometer reading)

The equation from Dafni (1992) was used to determine the amount of sugar per flower as follows:

$$\text{Amount of sugar (A)} = \frac{\text{\% of sugar reading in the refractometer}}{100} \times \text{A volume } (\mu l) \times \text{Density of sucrose at the observed concentration}$$

Estimation of sugar and Honey Production Potential (HPP)

The potential for producing honey was calculated by dividing the average number of flower heads per plant by the average quantity of nectar sugar per flower.

From the average number of flowers per tree and the average mass of sugar per flower, the average amount of honey that can be harvested from a single tree was calculated (Masierowska, 2003).

This information was used to calculate the potential honey production per plant and, further, the potential honey production per hectare for each individual trees of *D. torrida*. Based on the land area needed for each plant species and canopy coverage, the estimated number of plants per hectare was calculated (Bareke et al., 2020b).

One kg of ripe honey is expected to have an average moisture content of 18% while the sugar content is 82%. Therefore, the honey per ha of *D. torrida* plants= sugar content per ha of *D. torrida* plants divided by 0.82 kg of sugar (Bareke et al., 2020a).

Data analysis

One-way ANOVA was used to analyze the gathered data. For mean separation between the treatments, Tukey Test was used. Moreover, a linear regression model was generated using the R software to examine how temperature affects the volume and sugar concentration of nectar of the plants.

Results and Discussion

Nectar secretion length

The study investigated the nectar secretion dynamics of *Dombeya torrida* flowers, revealing that these flowers secrete nectar repeatedly over a period of eight days (Figure 3). Throughout this period, the nectar volume varied significantly, showing a decreasing trend as the flowers aged. Peak nectar secretion occurred on the second day, while the lowest volume was recorded on the eighth day. By the ninth day, measuring the nectar volume became challenging, likely due to the impact of repeated measurements over the previous days, which may have caused the flowers to halt nectar production prematurely.

In natural conditions, however, *Dombeya torrida* flowers exhibit a longer nectar secretion period, ranging from 13 to 15 days, indicating a higher nectar production rate than in flowers subjected to repeated measurements. This suggests that the methodology of frequent nectar measurement might interfere with the natural nectar secretion process, potentially reducing the overall secretion duration and volume.

The findings align with the findings from the study by Bareke and Addi (2024) on *Pavonia urens*, which reported a nectar secretion period ranging from 9 to 12 days. This comparison highlights a pattern of nectar secretion duration in different species, emphasizing the importance of understanding species-specific nectar

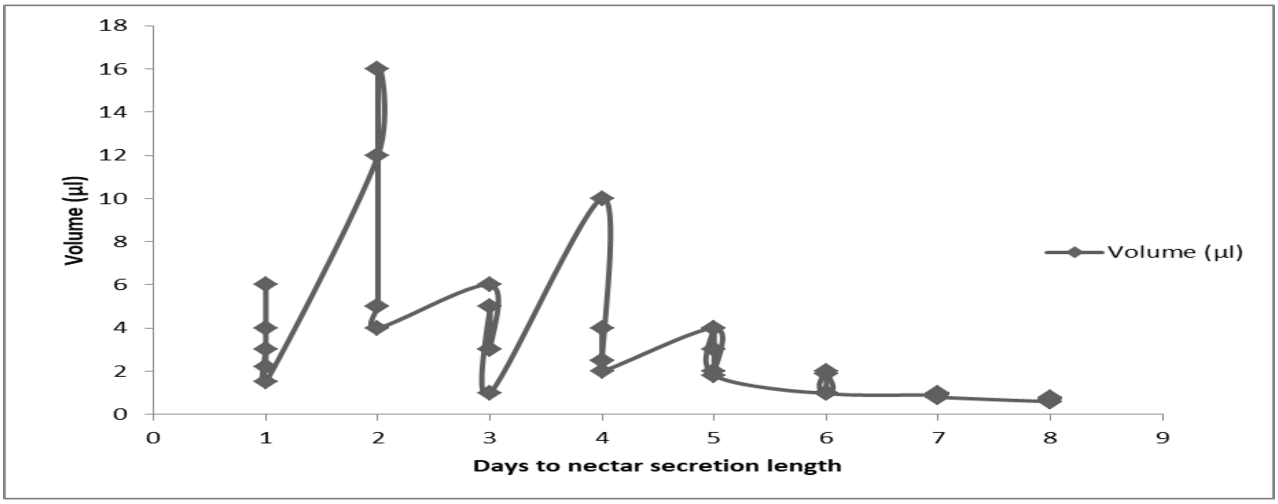

Figure 3. Nectar secretion length and volume of *Dombeya torrida* flower from start of secretion to end (repeated collection daily) (N=15 flowers daily from the start of secretion to end)

dynamics and the potential impact of measurement practices on these processes.

Nectar secretion dynamics

Nectar secretion dynamics vary significantly among different plant species and are influenced by both biotic and abiotic factors. For *Dombeya torrida*, the highest mean nectar volume was observed between 9:00 and 10:00 am, whereas the lowest volume was noted between 8:00 am and 12:00 pm. Furthermore, significant differences in mean nectar concentration were observed depending on the time of day ($P < 0.05$). The mean nectar content was lowest at 8:00 am and reached its highest volume from 9:00 am to 12:00 pm. Additionally, significant variations in the average quantity of sugar in nectar were found, with the highest mean amount recorded at 10:00 am and the lowest at 8:00 am (Table 1).

These findings align with other studies, indicating that nectar secretion patterns can vary considerably across different species. For instance, *Dombeya torrida* provides nectar between 8:00 am and 12:00 pm, while *Ziziphus spina-christi*, *Lavender* species, and *Coffea arabica* have been observed to secrete nectar throughout the day (Adgaba et al., 2012; Adgaba et al., 2015; Bareke et al., 2021). On the other hand, *Croton macrostachyus* secretes nectar from 8:00 am to 3:00 pm (Bareke et al., 2020b).

The significant variations in nectar secretion patterns among different honey source plants can be attributed to various biotic and abiotic factors associated with the plant species in their respective environments or microclimates (Al-ghamdi et al., 2016). This indicates that nectar secretion times are species-specific. Variability in nectar secretion within the same plant species can be due to differences in the position of flowers on the flowering stem and the microclimate of the area (Bareke & Addi, 2022). Moreover, day-to-day weather variations can cause shifts in nectar secretion patterns, and morphological and phenological characteristics also influence nectar secretion (Adjaloo et al., 2015; Bareke et al., 2021).

Additional studies have reinforced these observations. For example, nectar secretion in species like the *Japanese honeysuckle* (*Lonicera japonica*) has been shown to peak during early morning and late afternoon, influenced by both temperature and humidity (Southwick & Loper, 1984). Similarly, the timing of nectar secretion in sunflowers (*Helianthus annuus*) is linked to the plant's phenology and environmental conditions, such as light and temperature (Pilati et al., 2014).

These studies highlight the complexity and variability of nectar secretion dynamics, emphasizing the need to consider both intrinsic plant characteristics

Table 1: Mean nectar volume (µL), nectar concentration (%) and amount of sugar (mg) in nectar per flower in 1 hour intervals per flower with ± standard error (SE) of *D. torrida* in 8:00 am to 12:00 pm hours of the day

Time (hour)	Average nectar volume (µL) ± SE	Average nectar concentration (%) ± SE	Average sugar amount per flower/1 h intervals
8.00	3.3 ± 0.[5b]	16.9 ± 0.5[b]	0.7 ± 0.2[b]
9.00	8.1 ± 1.0[a]	27.1 ± 1.4[a]	1.8 ± 0.4[ab]
10.00	8.9 ± 1.5[a]	28.7 ± 0.8[a]	2.2 ± 0.5[a]
11.00	5.9 ± 0.6[ab]	29.7 ± 0.9[a]	1.4 ± 0.23[ab]
12.00	2.4 ± 0.2[b]	28.7 ± 0.4[a]	1.1 ± 0.2[ab]

Note: Different letters show significant differences and extrinsic environmental factors when studying and comparing nectar production across different species.

Effect of temperature on nectar secretion of *Dombeya torrida*

The relationship between temperature and nectar characteristics in *Dombeya torrida* reveals significant ecological insights. Figure 4a indicates no significant relationship between temperature and nectar volume (R^2 = 0.001). Temperature and nectar volume of *Dombeya torrida* are negatively correlated, suggesting that higher temperatures lead to a decrease in nectar volume (Figure 4a). On the other hands, figure 4b demonstrates a positive relationship between temperature and nectar concentration (R^2 = 0.5252), indicating that as temperature increases; the concentration of nectar also increases (Figure 4b).

These findings align with previous research on other plant species, which has demonstrated similar temperature-related trends in nectar attributes. For instance, a study by Petanidou and Smets (1996) on Mediterranean plants found that higher temperatures resulted in increased nectar sugar concentrations but reduced nectar volumes. This inverse relationship is likely due to the increased evaporation rates at higher temperatures, concentrating the nectar sugars while reducing the overall nectar volume available to pollinators.

Moreover, nectar characteristics are crucial for pollinator attraction and plant reproductive success. The increased concentration of nectar sugars at higher temperatures could enhance the attractiveness of flowers to pollinators, providing a richer energy source. However, the reduction in nectar volume might limit the amount of nectar accessible, potentially impacting the frequency and duration of pollinator visits. Understanding these dynamics is essential for predicting plant-pollinator interactions under changing climate conditions, where temperature variations could alter the availability and quality of floral resources.

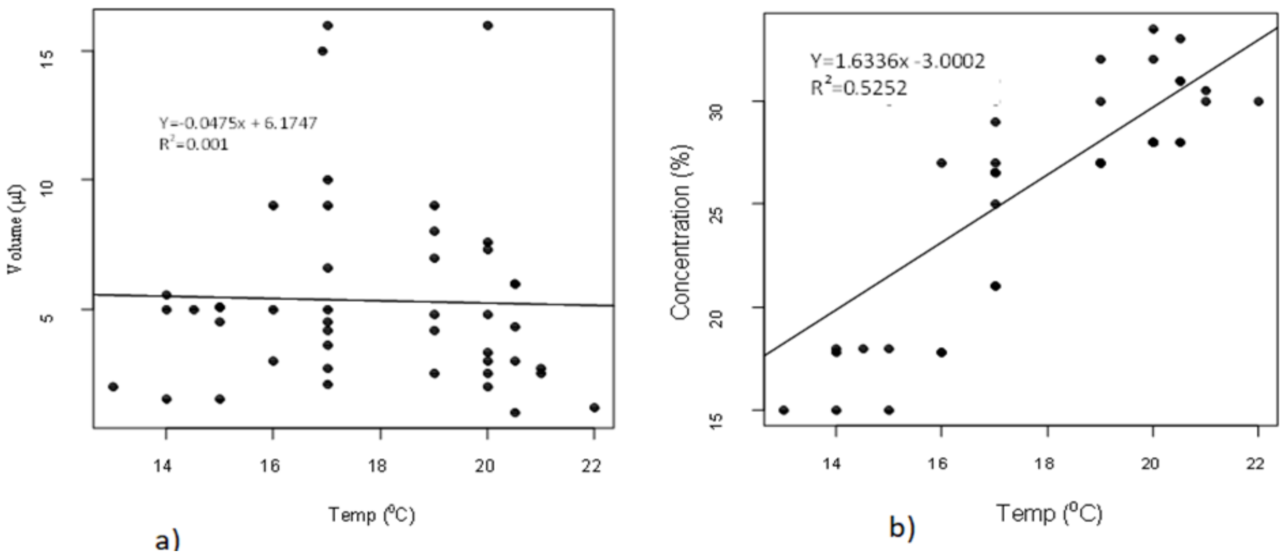

Figure 4: Variation of nectar volume (µL) (a) and nectar concentration (%) (b) of *Dombeya torrida* at different temperatures (°C).

The relationship between temperature and nectar secretion in *Dombeya torrida* demonstrates that nectar volume reaches equilibrium within a specific temperature range, with the highest secretion observed between 16 and 20°C. Outside this range, the nectar volume declines, underscoring that each plant species has an optimal temperature for nectar secretion. This observation aligns with a study on *Salvia leucantha* (Bareke & Addi, 2022), which also found that nectar volume reaches equilibrium due to the interplay of flower morphology and environmental factors, highlighting the variability in nectar secretion across different species.

The correlation between temperature and nectar concentration in *Dombeya torrida* aligns with findings in other species, indicating a direct positive relationship. For example, studies on *Schefflera abyssinica* (Bareke et al., 2020a) and *Coffea arabica* (Bareke et al., 2021) have shown that nectar concentration (solute quantity) increases with rising temperatures. Additionally, research conducted in southwest Saudi Arabia on *Lavandula dentata* and *L. pubescens* (Adgaba et al., 2015) revealed that nectar concentration significantly increases with temperature in both species.

Further supporting evidence can be found in studies on other plant species. For instance, research on *Eucalyptus melliodora* showed that higher temperatures led to increased nectar sugar concentration, likely due to enhanced evaporation rates (Nicolson & Thornburg, 2007). Similarly, a study on *Citrus sinensis* indicated that optimal nectar secretion occurred within a specific temperature range, with deviations leading to reduced nectar production (Pacini et al., 2003). These findings collectively highlight the critical role of temperature in influencing nectar characteristics across diverse plant species, emphasizing the importance of optimal temperature conditions for maximizing nectar secretion and concentration.

Honey production potential of *Dombeya torrida*

In a study, it was observed that *D. torrida* trees support an extensive number of flowers, with an average of nine branches per tree, ranging from four to twelve branches. Each tree was found to have between 35280 to 116000 flower heads, with an average of 65403 flower heads per tree (Table 2). This significant floral display indicates a substantial capacity for nectar production, which is crucial for honey production.

Previous studies have highlighted the importance of floral density and nectar availability in assessing a plant's potential for honey production. For instance, a study by Kevan and Baker (1983) noted that trees with large numbers of flowers tend to attract more pollinators, which is a critical factor in the production of high-quality honey. Similarly, research by Roubik (1989) emphasized that the abundance of blossoms on a single tree can significantly enhance the foraging efficiency of honeybees, leading to higher honey yields.

Table 2: Mean of branches per tree (N=24 tree), number of inflorescences per branch (N=72 branches), flower heads per inflorescence, flower heads per tree and nectar volume per flower head/24 hours (N=100 flowers) ± SE (standard error) and mean amount of sugar per flower of *D. torrida* in Chellia District, west Shewa Zone, Ethiopia

Parameters	Mean ± SE	Minimum	Maximum
Number of branches per tree	9.00 ± 0.80	4.00	12.00
Number of inflorescences per branch	169.00 ± 24.1	115.00	292.00
Number of flower heads per inflorescences	43.00 ± 1.50	38.00	49.00
Number of flower heads per tree	65403 ± 9078	35280.00	116000.00
Nectar volume per flower head/24 hours (µL)	5.01 ± 0.10	0.60	16.00
Amount of sugar per flower (mg)	14.3 ± 1.6	2.30	47.00

Each *D. torrida* tree produces an average of 0.94 kg of sugar per season, with observed ranges between 0.15 kg and 3.1 kg. This data is derived from the average sugar production per flower, which stands at 14.3 mg, with a range spanning from 2.3 mg to 47 mg (Table 2). These variations are attributed to factors such as tree age, environmental conditions, and overall tree health.

Given that 1 kg of honey with 18% moisture content (w/w) contains approximately 820 g of total dissolved sugar, the mean sugar yield from a single *D. torrida* tree (0.94 kg) translates to an estimated 1.2 kg of honey. The range of honey production per tree extends from 0.18 kg to 3.78 kg, reflecting the variability in sugar production.

The average *D. torrida* tree occupies around 40 m², allowing for approximately 250 trees per hectare of land. This density accounts for necessary spacing to ensure optimal growth and flowering. Consequently, during each flowering season, a hectare of *Dombeya* woodland has the potential to produce approximately 300 kg of honey, with possible yields ranging from 45 kg to 945 kg.

The mean sugar mass per plant of *Schefflera abyssinica* (Bareke et al., 2020a), and *Croton macrostachyus* (Bareke et al., 2020b) was greater than that of *D. torrida* (0.94 kg); (Bareke et al., 2020). This variation was occurred due to the size of the plant in addition to nectar secretion potential of the plant species. The bigger trees give better nectar and honey yield. The concentration, volume, and sugar of nectar are common factors that are important to pollination. The size of the flower, nectar volume, and solute content are the main factors that influence nectar collection technique (Dafni, 1992). Micropipettes are often used to extract the nectar volumes more than 0.5 µL and concentrations lower than 70%. Special methods are required to extract nectar from tiny flowers (Dafni, 1992).

Half of the plant's anticipated potential in honey production can actually be extracted from the hive (Bareke et al., 2019). Bees undoubtedly take some sugar for their flying energy during the collection and delivery of the nectar to the hives. Additionally, not all of the released nectar may be accessible to honeybees due to fast crystallization (Adgaba et al., 2012). A *D. torrida* plantation's potential honey yield per hectare was predicted to be 300 kg (with a range of 45 kg to 945 kg). This is comparable to the amounts of honey reported for *Ziziphus spina-christi* (550-1300 kg of honey/ha) (Adgaba et al., 2012), *Schefflera abyssinica* (481-3618.8 kg/ha/flowering season) (Bareke et al., 2020), and *Coffea arabica* (25 to 275 kg of honey/ha) (Bareke et al., 2021). The larger plant species produce more honey and have more flowers overall.

Conclusion

The study highlights the significant nectar secretion dynamics of *Dombeya torrida*, revealing a pattern of repeated nectar secretion over eight days under controlled conditions. In natural settings, the nectar secretion period extends to 13-15 days, indicating that frequent measurement practices may influence nectar production. Peak nectar secretion was observed on the second day, with a declining trend toward the eighth day. Nectar secretion dynamics were influenced by the time of day, particularly in the morning, with the highest nectar volume and sugar concentration recorded between 9:00 and 10:00 am. The concentration of the nectar is notably influenced by temperature variations, exhibiting fluctuations throughout the day.

Each *D. torrida* tree is estimated to yield 1.2 kg of honey, and a hectare of these plants could produce up to 300 kilograms, showcasing the species' immense promise for honey production. However, not all of the secreted nectar could be measured due to its fast crystallization and volatile nature, which may lead to an underestimation of the honey production potential of the *D. torrida*. There is competition between honey bees and other nectar collectors, such as different bee species, butterflies, and insects, that gather nectar from *D. torrida*. Since honey bees are abundant and have well-developed communication methods to exploit their environment, the competition from other insects is insignificant. The potential for generating monofloral honey from areas rich in *D. torrida* underscores the importance of multiplying and conserving this plant species in its natural habitat. This proactive approach can pave the way for sustainable honey production while preserving biodiversity and ecological balance.

Ethical Statement

There are no ethical issues with the publication of this article.

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Conflict of Interest

The author declares that there is no conflict of interest.

Author Contributions

Author 1: Investigation, Writing, review & editing; supervision and formal analysis (All parts done by me)

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