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Research Article

# Determining the Nectar Secretion and Honey Production Potential of Some *Acacia* Species in Waghimra Zone, Amhara Region, Ethiopia

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## ABSTRACT

The study aimed to investigate the nectar TSS and honey production potential of some *Acacia* species (*Acacia asak, Acacia etbaica*, and *Acacia tortolis*) in Waghimra zone, Amhara region, Ethiopia. Trees per hectare, flowers per tree, inflorescences per flower, nectar TSS per inflorescences were taken in this experiment. The number of trees in a hectare of land was counted in quadrat method while number of flowers counted in average of sampled trees. Flower inflorescences per plant were randomly selected from each studied *Acacia* species and nectar TSS was measured by washing technique using honey refractometer. Prior to nectar removal, flowers were covered with fine mesh bags on different parts of the trees and nectar sample was taken at a 3 hour interval for three days. The nectar TSS amount in a single flower of *A. asak*, *A. etbaica*, and *A. tortolis* has been estimated to be 10.19, 5.25, and 2.56 mg, respectively. In a hectare of land 105.6, 2020.2, and 2102.8 kg of honey yield was expected from *A. asak*, *A. etbaica*, and *A. tortolis* species, respectively. Nectar TSS of three *Acacia* species showed an increasing trend from early morning 6:00 am to 3:00 pm (after noon) and decreased to 6:00 pm. Temperature and Relative Humidity (RH) had showed positive and negative correlation with nectar TSS, respectively. In a hectare of beekeeping site, 105.6, 2020.2, and 2102.8 kg of honey yield was expected from *A. asak*, *A. etbaica*, and *A. tortolis* species, respectively. Despite the variations among the three *Acacia* species, a comparable honey yield was estimated to produce in the main flowering time of the species.

**Keywords:** *Acacia asak*; *Acacia etbaica*; *Acacia tortolis*; Nectar TSS; Honey yield

## INTRODUCTION

Honey bee plants are those plant species that provide bees with food sources in the form of nectar and/or pollen [1]. In this regard, 16% of the world's flowering plant species contribute to honey bees as food sources [2]. Moreover, not all bee plants are equally important to bees and honey production. Indeed, only 1.6% of the world's honey bee plants are the sources of most of the world's honey. This indicates that for every geographical region there are very few important honey source plants and it is of paramount importance to characterize them according to their degree of importance in honey production. In sexually reproducing species, nectar, the most important floral reward [3], is of vital importance in attracting pollinating animals. Extensive studies on the chemical composition of floral nectars indicate a dominance of sugars among the major classes of nectar constituents. Glucose, fructose, and sucrose are the major sugars and serve as the energy reward for pollinators [4].

Several authors have determined honey production potential for few honeybee plants, based on their nectar secretion potential including Tilia plant species [5]; Ziziphus spina-christi [6]; eight *Acacia* species (*Acacia asak*, *A. ehrenbergiana*, *A. etbaica*, *A. gerrardii*, *A. johnwoodii*, *A. oerfota*, *A. origena*, *A. tortilis*), four Lamiacae species (*Lavandula dentate*, *L. pubescens*, *Nepeta deflersiana*, *Otostegia fruticosa*), and two *Ziziphus* species (*Ziziphus nummularia Ziziphus spina-christi*); *Acacia ehrenbergiana* (Hayne) and *Acacia tortilis* [7] and *Croton macrostachyus* and *Schefflera abyssinica* plant species [8].

*Acacias* are important woody plants in many tropical and subtropical arid regions of the world [9] accounting for their

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significant biomass [10]. *Acacias* are well known as important sources of fuel, firewood, timber, forage, gum, tannins, fiber, folk medicine, and food and are also useful for environmental protection and soil and water conservation [11]. Different species of Acacia have been reported as important honey bee forages in many semiarid regions of the tropics. *Acacia* species, such as: *Acacia tortilis*, *Acacia asak*, *Acacia etbaica*, *Acacia saligna*, *Acacia abyssinica* and others, have been reported to exist in Ethiopia, but their roles in honey production have not been quantified and documented. There for the objective of this study was to investigate the nectar TSS and honey production potential of some *Acacia* species in Waghimra zone, Amhara region, Ethiopia.

# MATERIALS AND METHODS

## Study area

The study was conducted in Waghimra zone, Amhara region, Ethiopia, commonly known as the Tekeze corridor of the country. The area is situated at 12° N latitude and 38° E longitudes at an altitude of 500-3500 m.a.s.l with an annual rainfall of 150-700 mm which is an intermittent type of rainfall. The annual average temperature ranges from 15°C to 40°C. Small ruminant and honeybee colonies are the major livestock production types practiced in this area. About 595,054 goats, 222,089 sheep, and 130,771 honeybee colonies are assumed to be present in the study area [12]. Among seven three districts namely Gazgibla, Sekota, and Zequala were selected in Waghimra zone of Amhara region, Ethiopia representing highland, midland and lowland localities (Figure 1).

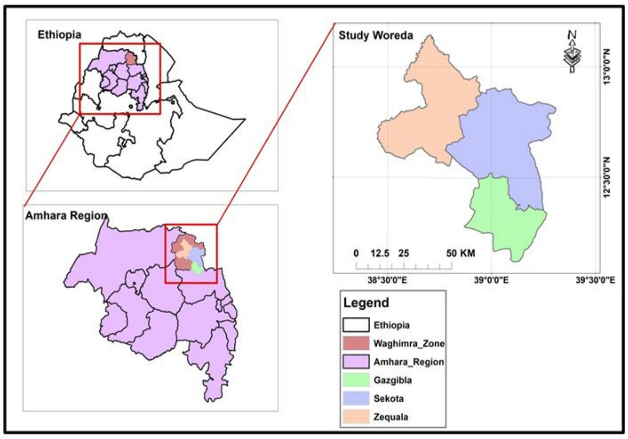
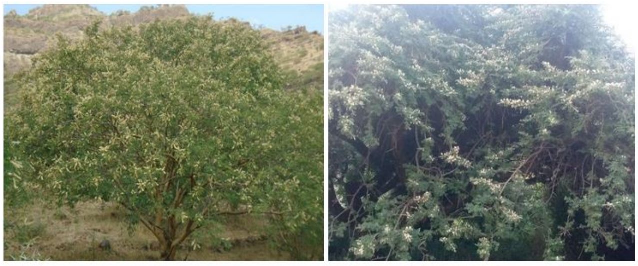



**Figure 1:** Map of the study area.

In this study, three important honey source plant species namely *A. etbaica*, *A. asak* and *A. tortolis* species were considered for nectar and honey yield estimation. By this *A. asak* was only abundantly available in Zequala (lowland) district; *A. etbaica* species was available in Gazgibla (highland) and Sekota (midland) districts; and *A. tortolis* honeybee flora species was available in all study locations of the area. The distribution variation mainly due to the climate and agro-ecology variability of the area and/or the niche differences of the species (Figure 2).



a. *A. asak* b. *A. etbaica*

**Figure 2:** Photos of *Acacia* species during blooming season.

## Nectar TSS estimation

In *Acacia* species with both spherical and elongated types of inflorescences, the individual florets are very small, and the nectar was too viscous (because of low humidity and high temperature of the study areas) to be easily measured using capillary tubes. Therefore, in this study, for all *Acacia* species, the flower buds were bagged one day before their flowers opened using bridal-veil netting [13] and the nectar TSS amount was determined following the flower nectar sugar washing techniques of [14]. In this procedure, one flower head was used only for one time measurement in that each flower head was removed and kept in a small, narrow plastic vial and washed with 1 ml of distilled water except for *A. tortilis* flowers which was enough to use 0.5 ml because of its smaller size. The flower heads were then left for 5 min until the sugar was completely dissolved. The nectar TSS was measured from five flowers per plant and for each sampling time (five times a day at 6:00 am, 9:00 am, 12:00 am, 3:00 pm, and 6:00 pm). The measurements were repeated for three consecutive days (Figure 3).

**Figure 3:** Photos in washing inflorescences of a flower in nectar TSS estimation.

## Honey yield estimation

The average amount of honey that can be obtained from a single plant was estimated from the average numbers of flowers per plant and the average mass of the nectar TSS per flower, following procedures similar to those of [15] and [16]. The honey yield expected was computed and expressed as in a hectare of beekeeping site.

## Weather data

Temperature and Relative Humidity (RH) of the study sites were recorded at each sampling time using an environment digital meter.

## Statistical analysis

The data were analyzed for statistical significance by Analysis of Variance (ANOVA), to compare the amount of TSS (mg) that was secreted per flower head per five hours period from the different trees, different locations and sample days. Mixed-effects Analysis of Variance (ANOVA) was used with the amount of nectar sugar/flower head as the response variable; the location, species, and time of day as fixed factors; and the trees as random factors. Independent t-test was used to test for the mean differences between study locations. A correlation analysis was performed between the environmental factors (temperature and RH of the area) and amount of nectar TSS (mg) secreted per flower.

# RESULTS

## Canopy volume, number of inflorescence and tree abundance of *Acacia* species

Mean canopy volume among the *Acacia* species was significantly different ($F_{2,807}$=335.56, P=0.001). In this regard, *A. etbaica* and *A. tortolis* species were the highest while *A. asak* was recorded having the lowest canopy size (Table 1). The mean number of inflorescences per tree was significantly different ($F_{2,807}$=163.5, P=0.001) among the *Acacia* species. Hence the highest and lowest mean numbers of inflorescence/tree were recorded for A. etbaica (23810.7) and *A. asak* species (11489.3). Similarly the mean number of trees per hectare was also showed a significant different among Acacia species ($F_{2,807}$=113052.25). The In a hectare of land, an average number of trees of 325.9, 97.9, and 859.4 trees of *A. etbaica*, *A. tortolis* and *A. asak* species was registered in ground inventory.

**Table 1:** Mean canopy volume (m$^3$), mean number of inflorescences per tree and mean number trees per hectare of *Acacia* species.

| Species | Mean canopy volume | Mean number of inflorescences per m$^3$ | Mean number of inflorescence tree$^{-1}$ | Mean number of trees ha$^{-1}$ |
|---|---|---|---|---|
| *A. etbaica* | 8.4$^a$ | 2767.3$^a$ | 23810.7$^a$ | 325.9$^b$ |
| *A. tortolis* | 8.2$^a$ | 2358.8$^a$ | 18786.6$^b$ | 97.9$^c$ |
| *A. asak* | 5.6$^b$ | 2079.3$^b$ | 11489.3$^c$ | 859.4$^a$ |
| P value | 0.001 | 0.001 | 0.001 | 0.001 |

**Note:** Different letters indicates significant variation among means and P value 0.001 represents high significant variation among means

The blooming period as well as the duration showed a variation among three *Acacia* species. Regardless of the blooming duration *A. etbaica* species had two blooming periods which is August to October and April to June. Among the acacias, *A. ask* species was recorded relatively long blooming duration starting from August to November (the main honey harvesting season of the area) in Zequala district. More importantly *A. tortolis* in all locations, the blooming period was during the dearth period of the area (February to April) which can support honeybees as the nectar and pollen source during the dearth period of the area. This different blooming time of this species have an advantage of different honey harvesting time of the area commonly two times a year which are in October and June depending on the rainfall distribution of the area (Table 2).

**Table 2:** Flowering distribution of some *Acacia* species.

| Species | Months of the year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June | July |
| *A. etbaica* | X | X | X | | | | | | | X | X | |
| *A. asak* | X | X | X | X | | | | | | | | |
| *A. tortolis* | | | | | | | X | X | X | | | |

## Nectar TSS and dynamics

The present study revealed that the nectar TSS amount per inflorescence among Acacia species has exhibited a significant difference ($F_{2,807}$=203.34, P=0.001) without considering the location of the each species (Table 3). The nectar TSS amount per inflorescence of *A. asak*, *A. etbaica*, and *A. tortolis* species has been estimated to be 10.19 ± 6.43, 5.25 ± 4.54, and 2.56 ± 1.39 mg, respectively. Therefore the highest and the lowest nectar TSS was recorded for *A. asak* and *A. tortolis* species, respectively.

**Table 3:** Mean ± Standard deviation ectar TSS (mg0) per inflorescence of three *Acacia* species.

| Name of the species | N | Mean ± Std. deviation |
|---|---|---|
| *A. asak* | 135 | 10.19 ± 6.43[a] |
| *A. etbaica* | 270 | 5.25 ± 4.54[b] |
| *A. tortolis* | 405 | 2.56 ± 1.39[c] |
| Over all mean | 810 | 4.73 ± 4.70 |
| P-value | | 0.001 |

**Note:** Different letters represent for statically different values and p=0.001 represents high significant value of means

## Nectar TSS with Location difference

The natural ecology of locally available *Acacia* species were varied according to the natural characteristics of the species in which *A. asak* was only located in Zequala district while *A. etbica* was available in both Gazgibla and Sekota districts though *A. tortolis* located in Gazgibla, Sekota and Zequala districts of the study area. Moreover, *A. asak* is the most dominate honeybees‟ nectar and pollen source plant species in Zequala district of Waghimra zone which is responsible for large contribution of Ethiopian high quality honey.

In the present study the amount of nectar TSS of two *Acacia* species had a significant difference in between locations that the plant naturally existed. In this regard, *A. etbaica* with a significant variation (P=0.01) (Table 4), in Sekota district registered relatively higher amount of nectar TSS (6.03 ± 4.95 mg) than in Gazgibela (4.47 ± 3.96 mg). In the case of *A. tortolis*, there was a significant variation among locations (DF=2, P=0.013). A mean of 2.37 ± 1.38, 2.59 ± 1.46 and 2.72 ± 1.30 mg of nectar TSS was measured in Gazgibla, Sekota and Zequala districts, respectively.

**Table 4:** Mean ± Std. deviation of nectar TSS (mg) per inflorescence of *Acacia* species in different locations.

| Name of the species | Location | N | Mean ± Std. deviation |
|---|---|---|---|
| *A. etbaica* | Gazgibla | 135 | 4.47 ± 3.96[b] |
| | Sekota | 135 | 6.03 ± 4.95[a] |
| | P-value | | 0.001 |
| *A. tortolis* | Gazgibla | 135 | 2.37 ± 1.38[b] |
| | Sekota | 135 | 2.59 ± 1.46[ab] |
| | Zequala | 135 | 2.72 ± 1.30[a] |
| | P-value | | 0.013 |

**Note:** *A. etbaica* in two locations and *A. tortolis* in three locations have analyzed using T-test and F-test comparisons respectively.

## Nectar TSS in different hours

In data collection, nectar measurement was conducted in five sample hours of a day for three days in the main flowering time of studied species. In this regard the amount of nectar TSS of *Acacias* was significantly varied in three hours interval of a day (DF=4, P=0.001) (Table 5). The nectar TSS (mg) of *Acacias* had experienced in increasing trend starting from 6:00 am to 3:00 pm and collapsed to 6:00 pm of the day. The highest and the lowest nectar TSS (mg) record were measured at 6:00 am and 3:00 pm respectively (Figure 4). Therefore it could have been noticed that the nectar measurement of three studied *Acacia* species exhibited the same tendency with respect to time variation.

**Table 5:** Mixed-effects Analysis of Variance (ANOVA) results for the amount of nectar TSS/flower head as the response variable; location, species and time of day (hours) as fixed factors; and trees as a random factor.

| Source | Type | Sum of squares | df | Mean square | F-value | P-value |
|---|---|---|---|---|---|---|
| Intercept | Fixed | 18151.59 | 1 | 18151.59 | 174.64 | 0.006 |
| Location | Fixed | 1314.08 | 2 | 657.04 | 74.47 | 0.001 |
| Hour | Fixed | 1792.84 | 4 | 448.21 | 31.54 | 0.0001 |
| Species | Fixed | 4793.74 | 2 | 2396.87 | 55.6 | 0.001 |
| Tree | Random | 207.62 | 2 | 103.81 | 1.5 | 0.305 |
| Location * Hour | Fixed | 145.55 | 8 | 18.19 | 1.85 | 0.141 |
| Location * Species | Fixed | 61.22 | 1 | 61.22 | 148.22 | 0.011 |
| Location * Tree | Random | 35.31 | 4 | 8.83 | 0.98 | 0.555 |
| Hour * Species | Fixed | 239.31 | 8 | 29.91 | 2.65 | 0.047 |
| Hour * Tree | Random | 113.36 | 8 | 14.17 | 1.32 | 0.471 |
| Species * Tree | Random | 172.19 | 4 | 43.05 | 39.31 | 0.829 |
| Location * Hour * Species | Fixed | 24.84 | 4 | 6.21 | 0.59 | 0.683 |
| Location * Hour * Tree | Random | 157.33 | 16 | 12.34 | 0.78 | 0.566 |
| Location * Species * Tree | Random | 0.89 | 2 | 0.44 | 0.04 | 959 |
| Hour * Species * Tree | Random | 180.61 | 16 | 11.29 | 1.06 | 0.489 |
| Location * Hour * Species * Tree | Random | 85.02 | 8 | 10.63 | 0.89 | 0.522 |
| Error | | 8571.14 | 720 | 11.91 | | |

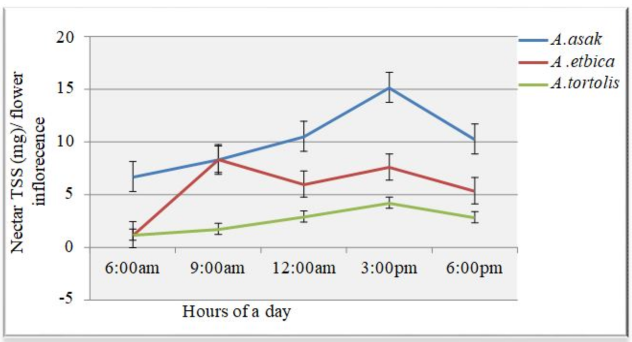



**Figure 4:** Nectar TSS dynamics of some *Acacia* species at different times of a day.

## Effect of temperature and air humidity on nectar secretion

The average temperatures and RH recorded during the study period varied from 19.2–41.5°C and 17.2–41% respectively. Temperature had a significant positive correlation with nectar TSS (r=0.32, p=0.01; r=0.73, p=0.01 and r=0.40, p=0.01 respectively) while RH had a significant negative correlation with nectar TSS (r=-0.32, p=0.01; -0.69, p=0.01 and -0.87, p=0.01 respectively) (Table 6 and Figure 5).

**Table 6:** Correlation (r) of nectar TSS amount with temperature and humidity of the air (RH) in three *Acacia* species.

| Species | Temperature (°C) | RH (%) |
|---|---|---|
| *A. etbaica* | 0.32** | -0.32** |
| *A. tortolis* | 0.73** | -0.69** |
| *A. asak* | 0.40** | -0.87** |

**Note:** **denots for high significant value among means at P<0.0 significant level and the positive and negative values indicates the positive and negative correlation values of the variables.

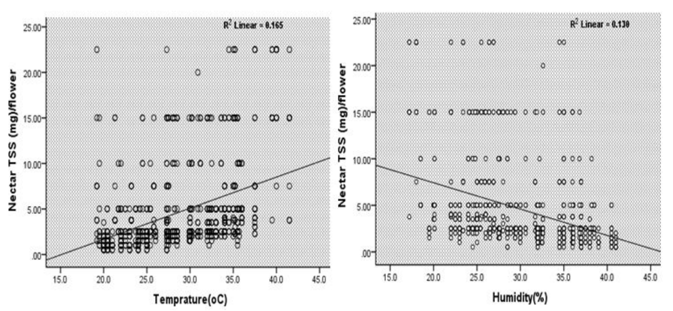



**Figure 5:** The effect of temperature and humidity (RH) on nectar TSS of some *Acacia* species.

## Expected honey yield

The amount of expected honey yield is the amount of honey estimated from the nectar TSS (mg) of *Acacias* which is utilized by honeybees. The average amount of honey that can be obtained from a single tree is estimated from the average number of flowers per tree and the average mass of the nectar TSS per flower, following the procedures. The present study revealed that in a hectare of beekeeping site 105.6, 2020.2, and 2102.8 kg of honey yield was expected from *A. asak*, *A. etbaica*, and *A. tortolis* species, respectively (Table 7). Hence by considering the nectar TSS amount and the number of single tree in a hectare of land, the highest average honey yield was expected from *A. etbaica* while *A. tortolis* and *A. asak* plants was the second and the lowest, respectively.

**Table 7:** Mean honey yield kg $ha^{-1}$ of some *Acacia* species.

| Species name | N | Mean | Std. deviation |
|---|---|---|---|
| *A. asak* | 135 | 105.6 | 65.5 |
| *A. etbaica* | 270 | 2020.2 | 2102.8 |
| *A. tortolis* | 405 | 2301.5 | 1446.4 |

# DISCUSSION

## Canopy, inflorescence number and tree abundance

In the present study *A. etbaica* and *A. asak* species had the highest and lowest in canopy size and inflorescence number among the three species, respectively whereas *A. asak* and *A. trtolis* species had the most and least number of trees per hectare among the three species. It is observed that large crowns can hold numerous numbers of inflorescence per trees while small crowns hold lower number of inflorescence per tree.

## Nectar TSS and dynamics

Unlike the previous general reports on the absence or trace amount of nectar in many *Acacia* species with spherical flower heads (sub genus *Acacia*). Similarly, substantial variation in the quality and quantity of nectar among different *Acacia* species has been well documented [17]. In this study, three *Acacia* species secreted large amounts of nectar sugar which may indicate these species potential for flower visitors and honey production. The nectar TSS amount in a single flower of *A. asak*, *A. etbica*, and *A. tortolis* has been estimated to be 10.19 mg, 5.25 mg, and 2.56 mg, respectively. Hence, *A. asak*, *A. etbaica* and *A. tortolis* species were the first, second and third nectar producer species in the study area respectively. Previously, an average of 1.8, 3.8 and 5 mg of nectar TSS was reported for *A. etbaica*, *A. tortolis* and *A. asak* species and an average of 1.94 ± 1.95 mg nectar TSS was estimated for *A. tortolis* species in the *Acacia* valleys of Saudi Arabiya. In this regard relatively high amount of nectar TSS was recorded from three studied *Acacia* species in the present study. This might because of the environmental difference of the study area that influences the nectar components of these species. The arid condition of Saudi Arabiya might reduce the TSS amount and even can affect the nectar secretion process of plant species. Accordingly, at high temperatures and low humidity, the amount of nectar available to bees and also the amount of honey that can be obtained would be below the estimated potential of the plant. Similar study also indicated that the variations in the amount and patterns of nectar secretion could observed in the different bee forage species [18]. Day to day variation in weather may cause shifts in the pattern of nectar characteristics; morphological and phonological characteristics have effect on nectar secretion. Large flowers may secrete more nectar than smaller ones at intra and interspecific levels as well as the flower phonological stage (protandry, protogyny, ageing) also influences nectar production [19].

For all species nectar secretion begins early (6:00 am) and continues to increase until 3:00 pm. Distribution of nectar secretion over most of the day time would be an important adaptation of the species to attract visitors for a longer time throughout the day to ensure pollination. In this study, the positive correlation between the temperature and amount of nectar sugar may indicate the adaptation of the species to hot climatic zones. The presence of a positive correlation between the temperature and nectar secretion was observed for *Thymus capitatus* under Mediterranean conditions [20] and for *Ziziphus spina-christi species*.

Nectar secretion and sugar concentration are temperature dependent plant biological activities that found a significant effect of temperature on nectar secretion, with a negative effect of very high temperatures in all species [21]. In the present study, the amount of nectar TSS secreted has sig indicant positive correlation with the ambient temperature and negatively correlated with RH. Hence the result was in line with, the ambient temperature had a significant positive correlation while RH had a significant negative correlation with nectar values (volume/flower, TSS content, and concentration in all species of Saudi Arabiya, which may indicate the adaptations of the species to higher temperatures and low humidity. The presence of a positive correlation between the temperature and nectar secretion was observed for *A. ehrenbergiana* and *A. tortolis* species under Saudi conditions. Similarly, in southern Saudi Arabia reported that the amount of nectar per flower of two lavender species significantly increased with an increase in temperature. Accordingly, at high temperatures and low humidity, the amount of nectar available to bees and also the amount of honey that can be obtained would be below the estimated potential of the plant. Similarly, the study conducted by A. Nuru et al., also indicated that the variations in the amount and patterns of nectar secretion by the different bee forage species.

### Expected honey yield

Expected honey yield per species per hectare was computed as by the amount of nectar TSS (mg) multiplied by the abundance of a species in each study site and the average was taken. In a hectare of land, the potential of three *Acacia* species for honey production was 105.6 kg, 2020.2 kg, and 2102.8 kg for *A. asak*, *A. etbaica*, and *A. tortolis* species respectively. The present finding is similar with some species which are previously reported. For example in Saudi condition, about 275.70 and 163.41 kg $ha^{-1}$ of honey could have produced in *A. ehrenbergiana* and *A. tortilis*, forests, respectively. In addition *A. syriaca* L. (milkweed) (500–600 kg honey/hectare; *T. pratense* L. (red clover) honey yield of 883 kg/ha/flowering period; various Tilia (lime) species (90–1200 kg honey/hactare; and *Brassica juncea* and *Sinapis alba* crops (65.5 kg and 71.2 kg/hectare, respectively. Moreover estimated honey yield for three *Acacia* species could have taken as meaningful result in Apiculture potential of the study area despite the variation among three species. This estimated honey yield helps for judgment of established honeybee colonies and after all for monitoring of honeybee colonies management.

## CONCLUSION

The present study revealed that the estimation of nectar TSS and honey yield potential of important honeybee plants could have been an interesting task in quantifying the apiculture value of the nature. By this investigation *Acacia* species were found the major honeybee floras registered in Waghimra zone of Amhara region, Ethiopia. Variation in flowering time of three species allows honey production in different season of the study area. Despite the limited rainfall and high temperature in the study area; *A. asak*, *A. etbaica*, and *A. tortolis* species produced significant amount of nectar TSS during the main flowering time of respective species and are a very potential species for beekeeping and honey production. In conclusion with the highest tree abundance and nectar TSS amount of *A. asak* in Zequala district, estimated to have been produced the highest expected honey production among the three species. Hence in *Acacia* vales of Waghimra zone it could have been expected a good crop of honey if a proper colony number is introduced and/or proper honeybee colony management is done. Therefore based on the estimated amount of honey expected from this *Acacias* in a hectare of land it can be also obtained the honeybee colonies carrying capacity of the area. Hence beekeepers should have been guide by this investigation during beekeeping site selection. This important nectar produced plant species should be protected and planted for increasing the amount of honey produced in a hectare of land. Lastly similar research works should have done for detail report of some other important honeybee floras in the study area.

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