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Research Article

Performance Evaluation and Honey Production Potential of Adapted Vetch Varieties for Bee Forage Development

Mekonen Wolditsadik*, Taye Beyene, and Desta Abi

Apiculture Research Team, Adami Tulu Agricultural Research Center, Ethiopia

Abstract

The study was conducted to assess the performance, quantify the nectar secretion dynamics, and evaluate the honey production capacity of Vicia atropurpurea, Vicia villosa, and Vicia sativa. The East Shewa and West Arsi zones shown good performance by Vicia atropurpurea, Vicia villosa, and Vicia sativa. Before nectar collection, a group of flowers was enclosed with mesh bags to measure nectar volume of the plants. The measurements of nectar volume, concentration, temperature, and humidity were generally taken at different times of the day. One-way ANOVA and descriptive statistics were used to analyze the collected data. Nectar secretion dynamics of the three Varieties were significantly varied (at $p < 0.05$) at different times of the day. The nectar volume that became available between the two consecutive measurements (three-h intervals) varied from 0.82 to 1.82 µl/fower, 0.94 to 1.8 µl/fower and 1.04 to 2µl/fower for Vicia atropurpurea, Vicia villosa and Vicia sativa, respectively. The temperature was positively correlated with the nectar concentration for the three varieties. However, the nectar volume of Vicia atropurpurea, Vicia villosa and Vicia sativa was negatively affected by temperature. The nectar concentration three varieties were also negatively affected by humidity. Whereas it is positively correlated with nectar volume for Vicia atropurpurea, Vicia villosa and Vicia sativa. However, the relationships between humidity and nectar volume were almost found at equilibrium for three varieties. Based on the mean amount of nectar sugar secreted by the plants, the mean honey production potentials of the species were estimated to be 101.5kg, 130.5kg and 139.2 kg/ha of Vicia atropurpurea, Vicia villosa and Vicia sativa, respectively. Therefore, the multiplication and management of these three vetch varieties (Vicia atropurpurea, Vicia villosa and Vicia sativa) are recommended for sustainable honey production.

Keywords: Pollen Yield; Nectar; Foraging Intensity; Concentration; Honey Potential.

INTRODUCTION

Apiculture is a floral based industry and bees wholly depend on plants for their food. From 250,000 plants in the world, about 40,000 plant species are important for honey bee. Bee colony performance as well as production of honey, wax and other hive products depends on bee forage. These food sources provide the nutritional requirements of the bee colonies. Nectar as sources of honey provides heat and energy for honey bees and pollen provides protein. Among the annual forage legumes, vetches are more promising as source of bee forage and short-term fodder crops. According to Tura, Kibebew and Admasu Vicia sativa were performed better under both rain fed and irrigation conditions in mid and highland agro ecology of the country. Developing better performing plant species through use of irrigation and rain fed conditions will alleviate the shortage of bee forages and increasing honey production. Vetch is used as a source of nectar and pollen for bee forage.

Among the many flowering plants, some of the plant species supply both nectar and pollen abundantly. The diversity of flowering plants and their flowering duration differ from one place to another. In our country, the knowledge of nectar secretion dynamics and potential for honey production is relatively at an infant stage. For many important bee forage plant species, nectar secretion capacity and its contribution to honey production have not been documented yet. These plants include three important vetch varieties includes, *Vicia atropurpurea*, *Vicia villosa and Vicia sativa* is annual herb with belongs to Fabaceae family [1]. It grows in midland, lowland and highland agro ecology. It also used as animal forage. Honeybees collect pollen and nectar from the flowers frequently [1]. These vetch varieties can grow from 30cm to 200cm. These plants are given flowers by irrigation and rain fed it is an excellent source of bee forage. However, nectar secretion dynamics and honey production prospective of these plant species have not been known. Therefore, the main objective of this study was to identify the performance, nectar secretion dynamics and estimate honey production potential of *Vicia atropurpurea, Vicia villosa and Vicia sativa*.

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***Corresponding author:** Mekonnen Wolditsadik, Apiculture Research Team, Adami Tulu Agricultural Research Center, P.O. Box 35, Ziway, Ethiopia

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MATERIALS AND METHODS

Study Area

The study was conducted in East Shewa and West Arsi Zones of Oromia for three years (2022–2024). The three Vetch varieties (*Vicia atropurpurea, Vicia villosa and Vicia sativa*) were selected based on their ecological adaptation range, foraging intensity of honeybees, and accessibility of the flower for nectar measurement.

Materials used

Micropipettes and micropipettes 'tips were used for the nectar collection. A digital refractometer was used to measure nectar concentration, whereas a hygrometer measured temperature and humidity at the same time.

Research Methods

The seeds were sown on plot size of size of 3mx3m arranged in randomized block design with four replications. The necessary agronomic practices (viz., weeding etc.) Were carried out except no fertilizer application to keep its natural growing state. The planting was

done under rain fed Conditions. Then, data on the days to germinate and average flower opening time was recorded. At 50% flowering, the number of flower heads was counted for each species by taking $1m^2$ plots as well as foraging intensity of honey bees on flowers was counted starting from 6: 00a.m. To 6:00p.m. For ten minutes at every 2-hour interval. Also, pollen yield of each variety was determined by collecting 50 matured flower heads having a similar age and was kept for certain days to dry. For removal from the flower, pollen was shaken on a paper tray and weighed using a sensitive weighing balance. Time, from blooming to shedding was also recorded.

Estimating the Number of Flowers per Plant and Plant per Area: Ten plots were randomly taken to determine the number of plants per area of each site. Plot size was 1m ∗ 1m for each variety. Plants per plot were taken to count the number of flowers per plant. Accordingly, the average number of flowers per hectare = average number of plants/ha ∗ average flower/plant

Nectar Volume and Concentration Measurement: Prior to nectar removal, the inflorescences were covered with fine mesh for 24 hours to prevent visitors. Flowers were marked at random from different inflorescence parts [2]. Accumulated nectar for 24 hours was taken from 20 flowers at random per day for three days [3].

1. Identifying the Nectar Secretion Duration: Time of opening of flowers, pollen release, and nectar secretion were taken. Fifteen (15) individual flowers were measured daily from the start to the end of nectar secretion to determine the nectar secretion duration [4].

2. Determining Nectar Secretion Dynamics: Data on nectar volume, nectar concentration, temperature, and humidity were taken at three-hour intervals from 6:00 to 18:00 hours simultaneously [2]. Depending on the nectar secretion durations of plant species. For each plant and sampling time, the nectar volume was measured from an average of 5 individual flowers at a time [3].

3. Calculation of Sugar Amount in Nectar per Flower: The amount of sugar found in nectar was calculated from the nectar volume, concentration, and sucrose density. Nectar concentration was converted to sucrose density using Pryjones and Corbet's [5] equation. The amount of sugar was calculated using the [6] equation.

3. Estimation of Honey Production Potential (HPP): Honey production potential of plants was estimated as the following: Average amount of sugar per hectare = Average number of flowers per ha ∗ average amount of sugar per flower ∗ nectar secretion days. Average amount of sugar per m^2 was converted to hectares [1,6,7]. The mean amount of sugar per hectare was converted to honey. In the international market, the average moisture content of the honey is 18% from 1 kg while 82% is sugar. This was used to convert the mean amount of sugar produced per hectare per flowering season to honey. The honey estimated from the sugar was the honey production potential of the plants [8].

4. Data Analysis: The collected data were analyzed using descriptive statistics and one-way ANOVA. Tukey was used for mean separation among the treatments.

RESULTS AND DISCUSSIONS

Plant Growth performance

In this study three vetch varieties (*Vicia atropurpura, Vicia villosa and Vicia sativa*) were sown in east sea and West Arsi zones, and the mean Values of germination date (GD) of the plant species are shown (Figure 1). There were different germination dates in east sea and West Arsi zones between the same plant Varieties. V*icia atropurpura, Vicia villosa and Vicia sativa* had the shortest germination date in east shewa (Adami Tulu Agricultural Research Center) and long germination date in West Arsi (Negele Arsi and Kofale) which might be related to low temperature in this site (Figure 1). This may be due to the variation of the temperature, soil condition and germination behavior of the plants at each study site [9]. The life cycles of plant germination and emergence of plants are the two most important factors that determine the efficient use of the nutrients and water resources available to plants [10]. *Vicia atropurpura, Vicia villosa and Vicia sativa* started Seed germination 5-6 days. In east shewa (Figure 1(a)). In contrast, germination of *Vicia atropurpura, Vicia villosa and Vicia sativa* were longer in west Arsi 7-10 days (Figure 1(b)).

Mean time taken to set flower for three vetch varieties, *Vicia atropurpura, Vicia villosa and Vicia sativa* were 48,45.3 and 46 days respectively (Figure 1(a)). Mean time taken to set flower for all three varieties was not significant (P>0.05). Because all three varieties were found under one species. Mean time taken to set flower for *Vicia atropurpura, Vicia villosa and Vicia sativa* were 63, 65 and 66 days respectively, and flower shedding occurred after 80 days in West Arsi (Table 3). Mean time taken to set flower for *Vicia atropurpura, Vicia villosa and Vicia sativa* at each agro ecology was statistically significant (P<0.05). Mean time taken from the start of blooming to shedding was similar for *Vicia atropurpura, Vicia villosa and Vicia sativa* with the range of 60 to 67 days in east shewa (Table 2). *Vicia atropurpura, Vicia villosa and Vicia sativa* took long days from flower opening until shedding at in

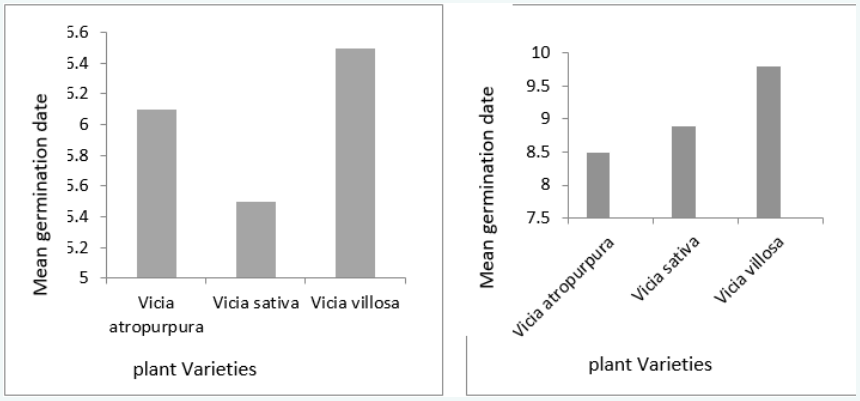


Figure 1: Mean Germination Day of bee forages at east shewa (a) and West Arsi (b) zones

Table 1: Descriptions of study area

District	Altitude	Rainfall	Temperature
Adami Tulu	1500-2300 m.a.s.l.	500-900mm	18.5-21.6°C
Nagele Arsi	1500-3000 Marseille	500- 1000mm	10-25°C
Kofale	2000-3050masl	1753-2200mm	14.5-15.5°C

Table 2: Mean time taken to set flower, pollen yield of 50 flower heads, foraging intensity and time taken from blooming to shedding in east sea

Plant species	Pollen yield (g) ± standard error	Mean time to set flower (days) ± standard error	Foraging intensity (number) ± Standard error	Total time from blooming to shading (days) ±standard error
Viciaatropurpura	0.12±0.0	48± 0.0	30.4±2.46	65±0.0
Vicia sativa	0.3±0.0	45.3± 0.1	32±1.26	60±0.0
Vicia violas	0.1±0.0	46± 0.0	32.5±0.2	67±0.0

Table 3: Mean time taken to set flower, pollen yield of 50 flower heads, foraging intensity and time taken from blooming to shedding in West Arsi

Plant species	Pollen yield (g) ± standard error	Mean time to set flower (days) ±standard error	Foraging intensity (number) ±Standard error	Total time from blooming to shading (days) ±standard error
Viciaatropurpura	0.66±0.0	63±5	32.4±2.46	80±0.0
Vicia sativa	0.26±0.0	65 ±0.0	31.5±1.26	78±0.0
Vicia violas	0.01±0.0	66 ±0.0	29.5± 0.2	85±0.0

west Arsi (Table 3). These occur due to different factors such as growing temperature; photo period [11]. Moreover, availability of moisture in the soil also increases the duration of flowering. Bee forage plants which take a long time from blooming to shedding are very important for honey production, whereas those that have short flower shedding time may be only used for bee colony build up.

Pollen yields were lower for all varieties (*Vicia atropurpura, Vicia villosa and Vicia sativa*) in east sea and West Arsi (Table 2 and 3). These Varieties are more nectar sources rather than pollen.

The number of bee visits with in ten minutes per1m^2 at each study site was different for each Variety. *Vicia villosa and Vicia sativa* were highly visited by bees followed by Vicia atropurpura in east sea. *Vicia sativa and Vicia atropurpura* were highly visited in west Arsi (Nagelle Arsi and Kofale) (Table 3). The observations recorded shows that the foraging rates of the pollinators which were few in the early morning and late in the evening. The foraging time of honeybees to different Vetch Varieties varied and with peak foraging time ranges from morning 8a.m-4p.m and 4a.m-4p.m in east sea and West Arsi zones respectively (Figures 2a,2b,2c).

Table 4: Mean nectar secretion length (day), flower/plant, flowers/ha, plant/ha, flowers/m^2, and plants/m^2 of *Vicia atropurpura*, *Vicia villosa* and *Vicia sativa*

	Vicia atropurpurea			*Vicia villosa/lalisa*			*Vicia sativa/gabisa*		
Parameters	Mean±std. Euro	Min	Max	Mean±std. Err	Min	Max	Mean±std. Err	Min	Max
Nectar sl (day)	7 ± 0.4	6.00	8.00	8 ± 0.4	7.00	9.00	7.8 ± 3.7	7.00	9.00
Flowers/plants, plant	380 ± 55.32	250.00	500.00	426.2±54.89	265.0	502.0	472.5 ± 42.9	350.0	550.0
Flowers/ha	22030000± 2642139.28	15000000	270000000	24320000± 2933837.03	15900000.0	29280000	27100000± 2609597.6	21000000	29560000
Plant per ha	57500± 2500	50000	60000	57500 ± 25000	50000	60000	57500± 2500	50000	60000
Flowers/m2	2203.0±262.2	1500.0	2700.00	2432.0 ± 29.39	159.	2928	2710 ± 260.9	2100	2956
Plants/m2	5.75 ± 0.25	5.00	6.00	5.75 ± 0.25	5.00	6.00	5.75 ± 0.25	5.00	6.00

Figure 2 Flowers of *Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa*

The mean nectar secretion lengths of three Vetch Varieties are similar which were 7, 8 and 7.8 for *Vicia atropurpura, Vicia villosa and Vicia sativa* respectively. The maximum nectar secretion periods were 8-9 days for each variety (Table 4). The mean number of plants per m^2 was 5 for *Vicia atropurpura, Vicia villosa and Vicia sativa*, because these all varieties were found under the same species and all are the same agronomic practices.

The mean flowers per plant were 380,426.2 and 472.5 for *Vicia atropurpurea, Vicia villosa and Vicia sativa* respectively. More branched plant species provide the highest number of flowers per plant. The mean number of flowers per plant varied due to the variation in size and age of the plants. A similar study conducted on *Hygrophila auriculata, Salvia leucantha, abyssinica* and *Croton macrostachyus* also revealed that the variations in number of flowers per plant could be attributed to the variations in their ecological distribution and climatic factors (temperature, rainfall, and wind).

Nectar Secretion Dynamics.

The highest nectar volume of *Vicia atropurpurea*,*Vicia villosa and Vicia sativa* were obtained at 15-18 hours while the lowest was at 12-9 hours (Table 5). Due to the nature of this plant (Table 5), the lowest nectar volume was found early in the morning until 9:00 hours. On the other hand, the highest nectar concentration (37.8%) was recorded at 15 hours while the lowest was at 6 hours (early in the morning). Nectar volume and concentration of *Vicia atropurpurea*, *Vicia villosa and Vicia sativa* were significantly different ($p < 0.05$) at different times of the day. The highest nectar volume of three vetch varieties (*Vicia atropurpurea, Vicia villosa and Vicia sativa*) was recorded at 15 hours whereas the lowest was early in the morning (at 6 hours) (Table 5). For many plant species, the nectar volume is the highest early in the morning due to the high humidity and low temperature of the local area. However, due to the nature of flower morphology of *Vicia atropurpurea*, *Vicia villosa and Vicia sativa* (Figure 3(a)), the highest nectar volume was obtained at the maximum humidity and temperature values of the study area. Similar study was conducted on *Hygrophila auriculata* (Schum.) and *Salvia leucantha* in south west shewa, the highest nectar volume was recorded when the humidity is higher. On the other hand, the uppermost nectar concentration was obtained from 12–18 hours of the day while the lowest was at 6 hours both at East shewa (Table 5) and West Arsi zones (Table 6) (Figure 4).

Effect of Temperature and Humidity on Nectar Volume and Concentration.

The concentration of nectar was positively correlated with temperature for three different vetch varieties. However, the temperature was affecting the nectar volume of *Vicia atropurpurea, Vicia villosa and Vicia sativa*. As humidity levels increase, three vetch varieties experience a decrease in nectar concentration. However, the relationships between humidity and nectar volume were negatively correlated for *Vicia atropurpurea, Vicia villosa and Vicia sativa*. This indicates that every plant species has its own optimum humidity and temperature for nectar secretion. A similar study conducted on *Lavandula dentata and Lavandula pubescens* also showed that the two species have different optimum humidity and temperature levels for the secretion of maximum nectar [12]. Temperature (°C) was affecting the nectar concentration of *Vicia atropurpurea, Vicia villosa and Vicia sativa* (Figure 5(a)). The highest nectar concentration values were secreted between 20°C and 27°C for *Vicia atropurpurea, Vicia villosa and Vicia sativa*. On the other hand, the temperature was affecting the nectar volume of three vetch Varieties (*Vicia atropurpurea, Vicia villosa and Vicia sativa*) (Figure 5(b)).

This means as temperature increased the nectar volume decreased and vice versa. Humidity was also affecting the nectar concentration of *Vicia atropurpurea, Vicia villosa and Vicia sativa*. This means when humidity of the area increases, nectar concentration decreases and vice versa. Humidity of the study area has direct relationships with nectar volume (Figure 6(a)). The highest values of the nectar volume were found between 40% and 70% of humidity whereas the lowest values of nectar volume were obtained at 25-30% of the humidity. The temperature was positively correlated with the nectar concentration of *Vicia atropurpurea, Vicia villosa and Vicia sativa* (Figure 5(a)). The peak nectar concentration was obtained between 25°C and 30°C. The humidity of the study area was affecting the nectar concentration of *Vicia atropurpurea, Vicia villosa and Vicia sativa* (Figure 6(b)). At the lowest humidity the highest nectar concentration values were obtained. The relationship between humidity and the nectar volume of *Vicia atropurpurea, Vicia villosa and Vicia sativa* shows that when humidity of the area increases, nectar volume also increases. This means humidity of the area can affect nectar volume of the plants (Figure 6(a)). Hence, whether the values of humidity increased or decreased, its affect on the nectar volume of *Vicia atropurpurea, Vicia villosa and Vicia sativa*.

Effect of Weather Conditions on Nectar Secretion Dynamics

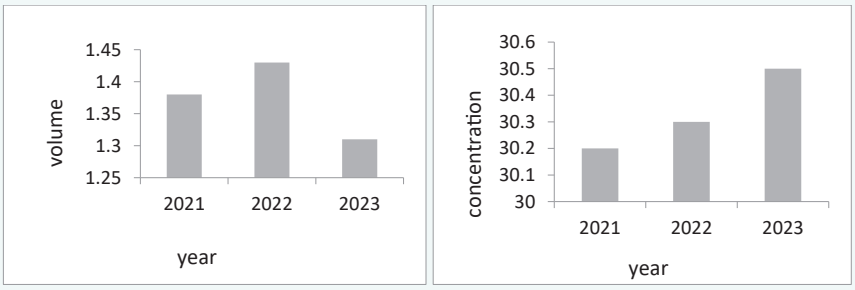
The nectar secretion duration of *Vicia atropurpurea, Vicia villosa and Vicia sativa* occurred during the whole day times. Microclimate determines the chances of changes in nectar volume and concentration; patterns of daily or seasonal changes in nectar variables; and pollinator behavior (frequency duration of visits, and foraging behavior) [6]. Nectar production is differed between the growing seasons due to environmental variables such as air temperature and humidity which can highly affect the nectar secretion and concentration of sugars [13]. The nectar secretion duration is varied from plant species to species. But no difference between plant varieties found under one species. For example: for *Antigonon leptopus and Tevetia Peruvians* from 6 h to 19 h [14] *Lavandula dentata and Lavandula pubescens* from 6 h to 18 h [15]; *Ziziphus spina-christi* from 6 h to 18 h [15]; and pear cultivars from 8 h to 19h. Floral durability plays an important role in reproductive ecology, influencing the total number of visits by honeybees and other pollinators as well as the honey production potential of the plants [15].

Table 5: Mean nectar concentration (%) and volume (µl) per flower at 3hour intervals with ± (SE) of the three vetch varieties (*Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa)* at 6:00-18:00 hours in East shewa Zone

	Vicia atropurpurea		*Vicia villosa/lalisa*		*Vicia sativa/gabbisa*	
Time (h)	Volume ± SE	Cons. ± SE	Volume ± SE	Cons. ± SE	Volume ± SE	Cons. ± SE
6:00	0.82 ± 0.11^{c}	19.4 ± 0.9^{d}	0.94 ± 0.4^{a}	23.0 ± 3.9^{c}	1.04 ± 0.6^{b}	25.2 ± 3.0^{c}
9:00	1.3 ± 0.15^{a}	30.05 ± 0.4^{c}	1.16 ± 0.1^{ab}	32.3 ± 2.3^{b}	1.3 ± 0.18^{b}	31.5 ± 0.8^{a}
12:00	1.7 ± 0.12^{ab}	32.5 ± 1.3^{b}	1.8 ± 0.2^{b}	36.4 ± 3.0^{a}	1.8 ± 0.2^{a}	30.6 ± 0.4^{a}
15:00	1.82 ± 0.27^{ab}	37.4 ± 0.8^{a}	1.6 ± 0.2^{b}	37.8 ± 2.3^{a}	1.9 ± 0.52^{a}	32.5 ± 0.70^{a}
18:00	1.27 ± 0.24^{a}	31.0 ± 0.9^{b}	1.04 ± 0.0^{ab}	31.9 ± 1.5^{b}	1.14 ± 0.1^{b}	30.3 ± 0.25^{a}
Mean	1.38± 0.17	30.07 ± 0.86	1.31 ± 0.18	32.2 ± 2.6	1.43 ± .18	30.02 ± 1.03

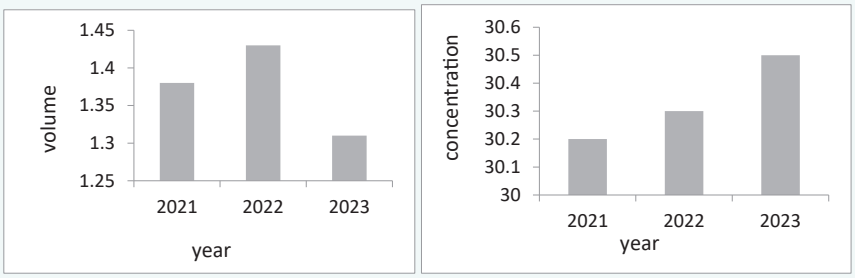
Table 6: Mean nectar concentration (%) and volume (µl) per flower at 3 hour intervals with ± (SE) of the three vetch varieties (*Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa)* at 6:00–18:00 hours in West Arsi zones

	Vicia atropurpurea		*Vicia villosa/lalisa*		*Vicia sativa/gabbisa*	
Time (h)	Volume ± SE	Cons. ± SE	Volume ± SE	Cons. ± SE	Volume ± SE	Cons. ± SE
6:00	0.82 ± 0.07^{c}	19.2 ± 1.0^{d}	0.98 ± 0^{a}	22.8 ± 3.7^{c}	1.0 ± .09^{b}	24.8 ± 1.7^{c}
9:00	1.48 ± 0.1^{a}	30.05 ± 0.73^{b}	1.26 ± . 08^{ab}	32.4 ± 2^{b}	1.46 ± 0.27^{b}	30.9 ± 0.72^{b}
12:00	1.82 ± 0.2^{ab}	32.3 ± 0.74^{b}	1.8 ± 0.25^{b}	36.8 ± 3.2^{a}	1.96 ± 0.24^{a}	31.6 ± 0.48^{a}
15:00	1.9 ± 0.3^{ab}	37.9 ± 0.7^{a}	1.94 ± 0.18^{b}	37.3 ± 2.28^{a}	2.0 ± 0.25^{a}	32.5 ± 0.69^{a}
18:00	1.42 ± 0.21^{a}	30.6 ± 0.93^{b}	1.2 ± 0.01^{ab}	30.7 ± 1.05^{b}	1.26 ± 0.1^{b}	30.3± 1.00^{a}
Mean	1.48. ± .17	30.01 ± 0.82	1.43 ± 0.23	32.0 ± 2.44	1.53 ± 0.35	30.02 ± 0.91



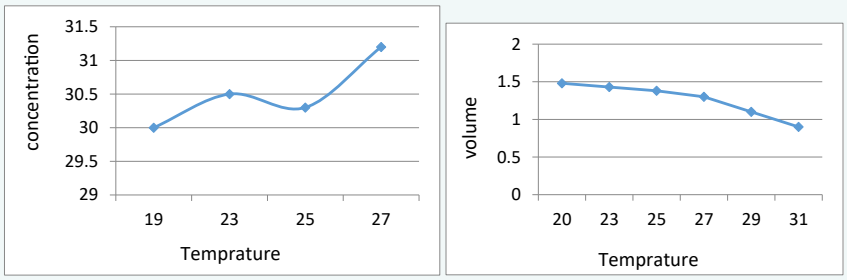
(a) (b)

Figure 3: Nectar concentration (b) and volume (a) *Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa* from 2021 to 2023 years in east shewa zone



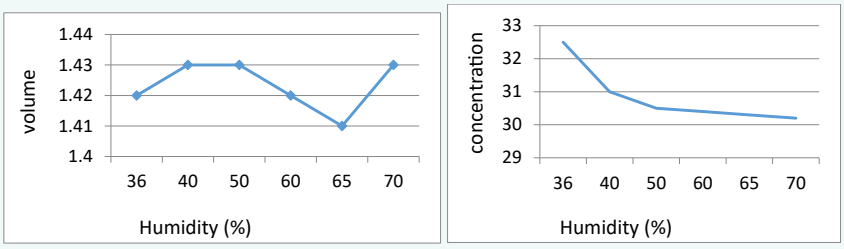
(a) (b)

Figure 4: Nectar concentration (b) and volume (a) *Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa* from 2021 to 2023 years in West Arsi zone



(a) (b)

Figure 5: Effects of temperature on nectar concentration (a) and volume (b) of *Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa*



(a) (b)

Figure 6: Effects of air humidity on nectar concentration (b) and volume (a) of *Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa*

Honey Production Potential

The mean number of flowers/ha of *Vicia atropurpurea* was 22030000 (ranging from 15000000 to 27000000) (Table 4) and it was used to estimate sugar per ha. The mean sugar per flower was 0.54mg/flower). Accordingly, when it was converted to honey, the mean amount of honey per ha of land was 101.5 kg (ranging from 59.2 to 142.24kg/ha). For vicia villosa mean number of flowers/ha was 24320000 (ranging from 15900000 to 27100000) (Table 4). These numbers were used to estimate sugar per ha and then converted honey. The mean sugar per flower was 0.55mg/flower). When it was converted to honey, the mean amount of honey per ha of land was 130.5 kg (ranging from 70.58 to 173.5kg/ha). The mean number of flowers/ha of *Vicia sativa* was 27100000 (ranging from 21000000 to 29560000) (Table 4) it was used to estimate sugar per ha. The mean sugar per flower was 0.54mg/flower). Accordingly, when it was converted to honey, the mean amount of honey per ha of land was 139.2 kg (ranging from 96.8 to 175.19kg/ha). The amount of honey obtained per hectare of land was 101.5 kg (ranging from 59.2 to 142.24kg/ha), 130.5 kg (ranging from 70.58 to 173.5kg/ha) and 139.2 kg (ranging from 96.8 to 175.19kg/ha) for *Vicia atropurpurea, Vicia villosa and Vicia sativa*, respectively. This variation shows the honey production potential of bee plants is varied from plant species to species. This variation occurred due to the nature of the plant, the habit of the plants as well as weather condition of the study area. For example: *H. Auriculata and S. Leucantha* provide honey of 29.8 kg/ha and 60.2 kg/ha, respectively, *Cofea arabica* 125 kg of honey/ha [16] and *Schefera abyssinica* 1791 kg honey/ha. The honey production potential of the bee plant species is very important to determine the number of honeybee colonies required to be placed in the selected area. This can be carried out with an effective foraging range (2 km radius or 4 km^2 area or 400 hectares) of honeybee colonies. Balancing several honeybee colonies with the available floral resource is used to harvest paramount honey by alleviating the problem of colony overstocking.

CONCLUSIONS AND RECOMMENDATIONS

Based on the dynamics and the amounts of nectar secreted per flower and per plant, three Vetch Varieties (*Vicia atropurpurea, Vicia villosa and Vicia sativa*) can be considered a potential honey source plant for the study area. Both temperature and humidity were responsible for the changes in the nectar volume and concentration of *Vicia atropurpurea, Vicia villosa, and Vicia sativa*. Nectar volume and concentration were significantly different at different times of the day. One hectare of *Vicia atropurpurea, Vicia villosa and Vicia sativa* plants has a capacity to give 142.2, 173.5 and 175.19 kg of honey respectively. Therefore, the multiplication and management of these three vetch varieties (*Vicia atropurpurea, Vicia villosa and Vicia sativa*) are recommended for sustainable honey production.

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REFERENCES

1. Kim SH, Lee A, Kang D, Kwon HY, Park Y, Kim MS. "Analysis of floral nectar characteristics of Korean and Chinese hawthorns (Crataegus pinnatifda Bunge). J Apic Res. 2017; 57: 119-128.
2. Wyatt R, Broyles SB, Derda GS. Environmental infuences on nectar production in milkweeds (Asclepias syriaca and A. Exaltata). Am J Bot. 1992; 79: 636-642.
3. Fichtl R, Adi A. HONEYBEE Flora of Ethiopia. 1994.
4. Bareke T, Kumsa T, Addi A. Nectar secretion and honey production potential of schefera abyssinica (Hochst. Ex, a. Rich.) Harms, araliaceae. Trop Agric. 2020; 97: 186-196.

5. Esteves MC, Villadelrey Rabajante JF. "Determining the optimal distribution of bee colony locations to avoid overpopulation using mixed integer programming. J Nature Studies. 2020; 9: 79-82.

6. Dafni A. Pollination Ecology: A Practical Approach, D Rickwood and BD Hames, Eds. 1992.

7. Prys-Jones E, Corbett SA. Bumblebees. Naturalists' Handbooks 6. 1991.

8. Bareke T, Kumsa T, Roba K, Addi A. Nectar secretion dynamics and honey production potential of Croton macrostachyus L., Euphorbiaceae. Bee World. 2020; 97: 123-127.

9. Debissa L, Admassu A, Amssalu B. Botanical inventory Phenology of bee plants in east shoa Zone. In ESAP Proceedings. 2005.

10. Gezahegn T. Adaptation trial of honey plants: adaptability trials of temperate honey plants in Ethiopia. Ethiopian Beekeepers Association newsletter. 2007; 5: 16-17.

11. Kenea GC, Abi DA, Beyene T, Tsadik MW. Comparative Study on the Adaptation of Selected HerbaceousBee Forages in Mid Rift Valley of Ethiopia. Global J Anim Sci Res. 2014; 2: 244-248.

12. Nuru A, Al-ghamdi A, Tena YT, Shenkut AG, Ansari MJ, Al-Maktary A, et al. Floral phrenology, nectar secretion dynamics, and honey production potential, of two Lavender Species (Lavandula Dentata, and L. Pubescens) in Southwestern Saudi Arabia. J Apic Sci. 2015; 59: 135-144.

13. Masierowska M. Floral nectaries and nectar production in brown mustard (Brassica juncea) and white mustard (Sinapis alba) (Brassicaceae). Pl Syst Evol. 2003; 238: 97-107.

14. Denisow M, Strzalkowska-Abramek M, Wrzesien M. Nectar secretion and pollen production in protandrous flowers of Campanula patula L. (Campanulaceae). Acta Agrobotanica. 2018; 71: 1-9.

15. Adjaloo MK, Ankomah AA, Yeboah-Gyan K, Dzomeku BM. Nectar production dynamics in two melliferous plant species. Genetics and Plant Physiology. 2015; 5: 145-161.

16. Bareke T, Admassu A, Kibebew W, Tolera K. Dynamics of nectar secretion, honey production potential and colony carrying capacity of Cofea, Arabica L (Rubiaceae). J Agric Environ. 2021; 115: 125-138.