Performance evaluation of local honey bee race (*Apis mellifera secutellata*) in the Metekel Zone of North Western Ethiopia

Esubalew Shitaneh¹ | Habtie Arega¹ | Mezgebu Getent² | Amssalu Bezabeh³

¹Ethiopian Institute of Agricultural Research, Pawe Agricultural Research Center, Pawe, Ethiopia
²Ethiopian Institute of Agricultural Research, DebreMarkos Agricultural Research Center, DebreMarkos, Ethiopia
³Oromia Institute of Agricultural Research, Holetta Bee Research Center, Holetta, Ethiopia

**Correspondence**
Esubalew Shitaneh, Ethiopian Institute of Agricultural Research, Pawe Agricultural Research Center, P.O. Box 25, Pawe, Ethiopia.
Email: esubeshianeh@gmail.com

**Abstract**
**Background:** Honeybee colonies differ in performance due to variations in their traits in terms of production, productivity and behaviour. The objective of this study was to identify and evaluate the performance of honey bee race at their geographical location.

**Methods:** A total of 20 honey bee colonies from traditional hives were transferred into frame hives and arranged randomly with enough space between the colonies. Colonies were evaluated for aggressiveness, hygienic behaviour, brood area, pollen and nectar stores, absconding and honey yield.

**Results:** The results indicated that colonies were generally aggressive, and the majority of colonies at 2.3-m away from the entrance reacted to the external body. They removed 95.7% ± 0.75% of the pin-killed pupae in 24 h, and there was significant (*p* < 0.05) variation among the different observations. The average population of the brood was 24.925 ± 7.714 unit area of brood/hive during the honey flow period. Similarly, the area allocated for storing pollen grains could reach up to 11.46 ± 3.96-unit area of pollen/hive. The swarming and absconding behaviour of the race was on average 3.39 ± 0.6, and 25% queen cells were found during the breeding season and dearth period, respectively. On average, the 8.85 ± 0.54 kg honey yield per colony per harvest on one honey chamber box was nearly similar to the national average (19.4 kg/hive/year) when harvested two times per year.

**Conclusion:** In general, the *Apis mellifera secutellata* race is good in hygienic tendency and also performs well for honey yield under optimal management practices. The absconding and aggressive behaviour was high; the main reasons were extreme weather condition, and different pest and disease, seasonality of bee flora were the major ones. So, based on the current findings *A. m. scutellata* was predominantly available in the area and highly productive if well-managed. On the other hand, we are recommended on dearth period management and on the height of shade bee colonies.

**Keywords**
*Apis mellifera secutellata*, aggressiveness, brood, pollen, nectar, absconding

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INTRODUCTION

Ethiopia is a land of geographical contrasts with elevations that range from 125-m below sea level in the Danakil Depression to 4533-m above sea level in the Semien Mountains, a world heritage site (Asefa et al., 2020). The diversified agro climatic conditions of the country create environmental conditions conducive for the growth of over 7000 species of flowering plants, of which most are bee plants (Nuru et al., 2002). Ethiopia is known for its tremendous variation of agro-climatic conditions and biodiversity, which favors the existence of diversified honeybee flora and huge number of honeybee colonies (Adgaba, 2007). Ethiopia is endowed with apicultural resources, while the production and productivity of the sector is still low. This could be attributed to many factors such as poor management, environmental factors and undesirable behaviour of local honeybee’s races; beekeeping research conducted in the nation so far did not cover to characterise and document the apicultural resources and associated constraints of the sector for its proper intervention and utilisation to specific potential regions (Chala et al., 2012). Honeybees of the high-land areas are larger in size, docile in behaviour and less productive, compared to the small lowland honeybees that are very aggressive and more productive. *Apis mellifera secutellata* is the second darkest and largest honeybee race next to *A. m. bandnsi*. It is distributed in the western, southern and southwestern humid mid-land parts of the country (Amssalu, 2004).

Honeybee colonies do not perform equally even under the same environmental conditions and managerial practices (Amssalu et al., 2002; Nuru et al., 2002), and the variations include all the desired and undesired traits in terms of production, productivity and behaviour.

It is known that the physical environment (biotic and abiotic) such as altitude, climate and vegetation greatly affects the behaviour and the productivity of colonies. Thus, performance evaluation of those honeybee races in their natural agro-ecological zone is crucial to assess the potentiality of the race and to lay a foundation for future selection and improvement of the local race (Tadele et al., 2014). Although beekeeping, like any other sector, has to be a profitable one, but the challenges faced in these sectors impede the importance of the commodity. Therefore, the purpose of this study was to identify and evaluate the performance of honeybee race at their geographical location.

MATERIALS AND METHOD

2.1 Description of the study area

The study was conducted at the Pawe agricultural research center in Pawe district, Metekel Zone of Benishangul Gumuz Regional state, from October 2014 to November 2017. It is located around 567 km northwest of Addis Ababa. The Metekel Zone was the largest zone of the region, covering an area of 3,387,817 ha and consisting of seven districts. The topography of the zone presents undulating hills slightly down to low land plateaus with varying altitudes from 600-2800 m.a.s.l. and an annual rainfall of 900–1450 mm. About 80% of the area is characterised by sub humid and humid tropical climates with annual minimum and maximum temperatures of 20°C and 35°C, respectively (Metekel Zone department of agriculture). The map of the study location is indicated in Figure 1.
2.2 | Experimental colony and management

A total of 20 colonies were allotted on station, and internal and external observations were performed for their efficiency. The colonies were transferred into frame hives and arranged randomly with enough space between colonies. Basic management practices (inspection, feeding, suppering and reducing suppers) were made reasonably uniform for the tested colonies. Performance evaluations of the colonies were studied through the defensive, hygienic, absconding, foraging, and swarming behaviours and the brood, pollen and honey store parameters.

2.3 | Evaluation of defence and hygienic behaviour

Temperament measures the aggressive behaviour of honeybee colonies. The aggressiveness of the colony was examined by hanging the black ball and hitting the entrance and lid. Then, the time taken to the first sting made, the distances following the examiner, and the number of stings on the black ball were evaluated. Then, necessary data/parameters like time of the first sting in the glove, time taken to be aggressive (mass attack), number of stings in the gloves of the observer and distance that the bees followed in defending, were recorded.

Hygienic behaviour was determined by a pin-killed brood assay (100 capped pupae). This section of the comb was marked by removing one entire row of cells surrounding the 100 cells. The number of empty cells within the section was counted and recorded when available. Then, every capped pupa within the section was pin-killed and placed back into the hive of the test colony. After 24 h, the frame with the section was taken out, and the numbers of remaining dead brood and the removed ones were recorded. This test was repeated five times for all the colonies to be tested for the hygienic behaviour. Finally, the percent of removal of dead brood was calculated by the following the formula (Kebede, 2006).

\[
R = \frac{K - E - C/T - E}{T} \times 100
\]

where \( R \) = percent removal of dead brood within 48 h; \( K \) = number of dead broods removed within 48 h; \( E \) = number of empty cells on both sides of insert before test; \( C \) = number of brood cells that remained capped after 48 h; \( T \) = total number of brood cells on both sides in an insert.

2.4 | Evaluation of absconding, swarming and foraging behaviour

Absconding tendency was assessed by the ratio of colonies evacuating to the total number of colonies used for the experiment provided that all the colonies were kept under uniform environmental conditions. The swarming tendency was evaluated by counting queen cells at 9-day intervals during the active season. Foraging behaviour was assessed by counting the number of bees flying out of the hives for 5 min in early foraging, and late foraging time was recorded.

2.5 | Evaluation of brood and adult area, pollen, nectar and honey storing behaviour

Those that had been evaluated to the individual colony by way of the usage of a square partitioned frame (10\( \times \)10 cm) and total brood area were evaluated every 21-day interval. The remaining comb occupied by each parameter was determined and measured appropriately in different seasons.

2.6 | Statistical analysis

The data collected in different parameters were analysed using SPSS software version 20, 2002. The mean comparisons were performed by using one-way analysis of variance via the least significant difference test at the (\( \alpha = 0.05 \)) level of significance.

3 | RESULTS

3.1 | Evaluation of the defensive behaviour of A. m. secutellata

Out of 20 observations made throughout the experimentation period, all of the colonies were countered at a distance of 2.3-m away from the hive entrance without knocking at the peak period. The average number of stings discovered at the entrance of the hive during the movement of the black ball was 52.75 \( \pm \) 9.5 stings. The average time taken to be aggressive (mass attack), number of stings in the gloves of the observer and distance that the bees followed in defending, were recorded.

| Parameters | Minimum | Maximum | Mean \( \pm \) SD |
|------------|---------|---------|-----------------|
| First time taken to lead reaction (s) | 2 | 4 | 2.50 \( \pm \) 0.35 |
| First sting on the ball (s) | 6 | 23 | 12.75 \( \pm \) 3.5 |
| Total time taken in aggressiveness (min) | 3 | 5 | 3.70 \( \pm \) 0.34 |
| Number of stings on the glove | 31 | 111 | 56.63 \( \pm \) 18.8 |
| Number of stings on the leather ball | 32 | 75 | 52.75 \( \pm \) 9.5 |
| Following distance in metre | 307 | 444 | 372.78 \( \pm \) 29.2 |

Source: Data taken from our experiment year 2014–2017.
3.2 | Evaluation of hygienic behaviour

The present result showed that colonies removed 95.7% ± 0.75% of pin-killed brood within 24 h at peak honey flow period. The details of the data about the hygienic behaviour of A. m. secutellata are described in Table 2 and Figure 3.

3.3 | Evaluation of absconding and swarming behaviour of A. m. secutellata

About 25% of colonies leave their nest at the dearth period (July, August and February) of the year. The main reason for absconding from a colony in the current study was suspected to be 38% by pests like wax moth, large and small hive beetle and environmental flux, 33% due to disturbance during any bee colony manipulation and 29% of the colony leave their hive during transferring time to the new hive. The result of A. m. secutellata honeybee’s reproductive swarming tendency is indicated in Table 3 and Figure 4.

On average, 3.39 ± 0.6 queen cells per colony were observed. Different year and observation data are indicated in Table 3.

3.4 | Evaluation of foraging behaviour

Counting of foraging worker bees were conducted for A. m. secutellata bee colonies during the peak flowering season. As the data indicated in (Table 4) show, the foraging behaviour of A. m. secutellata flows earlier in the morning at 6:01 PM within 5 min around 107.25 forager bees, much earlier, up to 6:11 PM. The majority of forager bees in bee hive foraging until 6:03 AM, whereas few forager bees stood late until 6:13 AM, which was the minimum value of forager bees recorded within 5 min.

3.5 | Evaluation of brood and adult area, pollen, nectar and honey storing behaviour of A. m. secutellata

As shown in (Table 5), an average area of 24.92 ± 7.71-unit area of brood/colony was recorded. The maximum pollen in the hive was 24-unit area/hive in November, and 2.75-unit area/hive pollen was...
FIGURE 3 Field photo taken during the evaluation of hygienic behaviour at the experimental site

FIGURE 4 Major reason of colony absconding in the study area

TABLE 5 The number of adult bee, brood area, pollen and honey area of colony per 10*10 cm²

| Parameter              | Minimum | Maximum | Mean ± SD |
|------------------------|---------|---------|-----------|
| Adult bee (unit area)  | 33.71   | 89.1    | 68.45 ± 9.87 |
| Honey area (unit area) | 7.38    | 50.05   | 26.07 ± 7.737 |
| Pollen area (unit area)| 2.75    | 24      | 11.46 ± 3.96 |
| Brood area (unit area) | 10      | 50.05   | 24.925 ± 7.714 |

Source: Data taken from our experiment year 2014–2017.

4 | DISCUSSION

4.1 | Evaluation of the defensive behaviour of A. m. secutellata

The average time taken for the first sting of the A. m. secutellata race was found to be higher than (Tesfa & Kasa, 2019) for A. m. bandnsi at 3.9 ± 2.9 s. This variation might be due to an indication of difference among bee races on defensive behaviour. The aggressiveness of bee colony was the major problem in the area. This makes colonies less productive because most of their time is spent on safeguarding of the home.

4.2 | Evaluation of hygienic behaviour

Our result proves that A. m. secutellata bee race was highly hygienic and seemed to react to different pests and diseases. Hygienic behaviour varied in agro-ecology when honeybees were present, and different seasons interfered with the daily activity of bees within the same colony. The colony is when good hygienic behaviour is an indication of shielding the home from external pests that destroy the colony.

4.3 | Evaluation of absconding and swarming behaviour of A. m. secutellata

The current finding supported the result of Bilatu et al. (2009), who found that on average, 11 bee colonies out of 19 were absconded per household every year, and the major factors that initiated bee colony absconding were different pests and predators. The disease, seasonality of bee flora and environmental fluctuations were the major factors. On the other hand, the current result of A. m. secutellata bee race

recorded as the minimum value during January. The mean honey yield in this study was 8.85 ± 0.54 kg per harvest per hive in one box (see Table 5).
indicated a high rate of reproductive swarming. This is because more food was available in the field during the peak flowering season, which makes bee colonies more populated, leading to the harvest of more food for the maintenance of generation, and the queen lays a large number of eggs for the building up of colonies for the next flowering season.

4.4 | Evaluation of foraging behaviour

The present result opposes with Abdulaziz et al. (2013), who found that a higher number of worker bees was recorded at 10:00 AM, and the lowest number of worker bees was observed at 4:00 PM. The area was almost 12 h of sunshine, which makes bee colonies forage early and evening, but at daytime, the area has a high temperature, which makes colonies forage early.

4.5 | Evaluation of brood and adult area, pollen, nectar and honey storing behaviour of A. m. secutellata

The time of the highest brood rearing season was similar to that in a study by Tesfa and Kasa (2019) during peak flowering time. Honeybees are affected by environmental conditions because they do not hibernate or diapause (Heinrich, 1996). Temperature is the most effective factor determining colony activity and bee strength. Dramatic variations in temperature may stop brood rearing or cause bee death (Abd, 1983; Graham, 1999). Although there are differences in race, geographical location and numerical value, they are related to the findings of Abdulaziz et al. (2013). Thus, the smallest pollen area was 11.00 sq./colony for A. m. Jemenitica (AMJ) in September, while the highest area (96.25 sq./colony) was recorded on 25 November for A. m. cerana (AMC). According to Tadele et al. (2014) 388.1 sq./colony nectar and 300.3 sq./colony pollen grain storage was recorded for AMC and AMJ. This variation may be a result of race differences in agro-ecological zones and more rigorous swarming of A. m. secutellata in our case than production. The result differed from the study of Tesfa and Kasa (2019), who found that the mean honey yield per harvest per hive was 14 ± 2. 9.67 ± 1.53 and 12.33 ± 4.5 in 2016, 2017 and 2018, respectively. The honey productivity of bee colonies depends on the type of honeybee races, agro-ecology, availability of pollen and nectar, health status of the colonies and strength of the colonies (Tesfa and Kasa, 2019).

5 | CONCLUSION

To summarize our results, A. m. secutellata races is situated in the north-western part of Ethiopia, mainly around the Metekel Zone and West Amhara region. The race has been an aggressive temperament that follows a mean distance up to 372.78 ± 29.26 m away from the nest and stings 52.75 ± 9.5 counted on a black leather ball. On average, A. m. secutellata race was a highly hygienic behaviour that removed 95.7 ± 0.75% of the pin-killed brood within 24 h during the peak honey flow period. The A. m. secutellata race was highly absconding, whereas the recognized reasons were extreme weather conditions, different pests and diseases and seasonality of bee flora. Based on the current findings, A. m. secutellata was predominantly available in the area and highly productive if well-managed. Therefore, we recommend seasonal management of bee colonies for better productivity and reconsider that the height of bee colony shade is essential.

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CONFLICT OF INTEREST
The authors declare that no competing interests exist.

ETHICS STATEMENT
The Ethical Committee of Ethiopian Institute of Agricultural Research and Pawe Agriculture Research Center livestock research process approved this protocol of research.

AUTHOR CONTRIBUTIONS
Esuabelw Shitaneh wrote the manuscript and conducted sampling and data analyses. Habtie Arega conducted sampling and coordinated the study. Mezgebu Getent coordinated and planned the study. Amssalu Bezabeh contributed to the study design and provided technical and management advice.

DATA AVAILABILITY STATEMENT
Data derived from public domain resources

PEER REVIEW
The peer review history for this article is available at https://publons.com/publon/10.1002/vms.3885.

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