RESEARCH ARTICLE
AGROBIOLOGICAL RECORDS
ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

EVALUATION OF PRODUCTIVE AND REPRODUCTIVE PERFORMANCE OF HONEYBEE COLONIES (*Apis mellifera monticolla*) IN SOUTH WOLLO, AMHARA, ETHIOPIA

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ABSTRACT

Despite the country's potential for apicultural resources, native races, productive and reproductive performances are at relatively low levels. Numerous factors, including environmental factors and honeybee races, may be to blame for this. As a result, this study was carried out to assess local honeybee race performance and choose the best colonies in the various agro ecologies of the study area. For this purpose, 90 colonies of *Apis mellifera monticolla* (30 colonies per agro ecology under on farm) were kept in improved box hives and assessed for egg area, larvae area, pupae area, nectar and honey area, as well as honey yield and swarming tendency. Egg sizes in the research area range from 519.25cm^2 to 1343.80cm^2, while larvae and pupae have respective sizes of 574.07cm^2 to 1407.05cm^2 and 618.76 to 1471.83cm^2. Dessie zuriya district had the highest pollen area, nectar area, honey area, and honey yield (15.28cm^2, 343.17cm^2, 386.13cm^2, and 22.13cm^2), followed by Kalu (8.97cm^2, 236.02cm^2, and 18.88cm^2), and Tehuledere (6.01cm^2, 142.54cm^2, 150.39cm^2, and 12.83cm^2, correspondingly). The development of queen cells and swarming behavior were unaffected by agro ecology. In general, compared to other ecotypes and races in the country, honeybee colonies in the study area generally performed better in terms of both productive and reproductive aspects. In this study, colonies located in the zone's highland performed better than colonies located in the study area's midland and lowland.

Keywords: Evaluation, Honeybee, Performance, Swarming tendency, South Wollo

Article History (ABR-24-205) || Received: 06 Jan 2024 || Revised: 18 Mar 2024 || Accepted: 21 Mar 2024 || Published Online: 22 Mar 2024

1. INTRODUCTION

Despite Ethiopia's potential for apiculture, production and productivity are still quite low. This may be due to a variety of causes, including management, environmental conditions and honeybee race differences. According to Mossie and Biratu (2019), the physical environment (such as altitude, vegetation, climate, etc.) has a significant impact on the behavior and productivity of honeybee colonies. Additionally, even under the identical environmental conditions and management approaches, honeybee colonies do not function equally (Abou-Shaara et al. 2013). The overall area of the colony's comb, which stores honey, pollen, and brood, the adult bee population, weight per bee and the colony nest cavity volume ratio all affect the performance (strength and production) of honeybee colonies (Margaret et al. 2011; Anthony et al. 2012).

In comparison to the small, aggressive, and productive lowland honeybees, the honeybees of the highland regions are larger in size, docile in temperament, and less productive (Tarekegn et al. 2022). Even within the same agro ecological zone, honeybee colonies behave differently (Mossie and Biratu 2019). All of the acceptable and undesirable features in terms of output and productivity are included in the variations. Even under the same environmental conditions and management techniques, honeybee colonies do not perform identically (Tarekegn et al. 2022).

While the environment has a significant impact on how different honeybee colonies differ from one another, a colony's genetic makeup can also affect the traits that distinguish one group from another. Beekeepers have used several strains to fit that particular function since they are knowledgeable about various genetic stocks that have unique traits (Meixner et al. 2013). Although some races in the nation are known for their color, size, and distribution, little is known about how they perform. In order to determine the potential of the races (local honeybees) and to lay the groundwork for future selection and enhancement of the local honeybees, performance evaluation of these honeybee races in their natural agro-ecological distribution is highly important. As a result,

Citation: Alebachew W, Tamir B, Amare T and Bezabh A, 2024. Evaluation of productive and reproductive performance of honeybee colonies (*Apis mellifera monticolla*) in South Wollo, Amhara, Ethiopia. Agrobiological Records 16: 49-56. https://doi.org/10.47278/journal.abr/2024.011

the objectives of the present study were: To evaluate the reproductive and productive performance of local honeybees at on farm level.

2. MATERIALS AND METHODS

2.1. Study Area

One of the 11 zones in the Amhara region, South Wollo zone has a total size of 17,067.45km^2 and is situated between 10°10′ to 11°50′ North latitude and 38°30′ to 40°10’ East longitude of Ethiopia (Fig. 1). Dessie town serves as the zone's administrative center. The zone has 20 districts, of which Tehulederie (middle), Kalu (lowland), and Dessie Zuria (highland) were specifically chosen for this study based on their beekeeping potential, accessibility and proximity to honey marketing and processing routes. The zone experiences annual rainfall on average of 1162mm. The monthly minimum and maximum temperatures are 12.6°C and 26.4°C, respectively (Bihonegn et al. 2017).

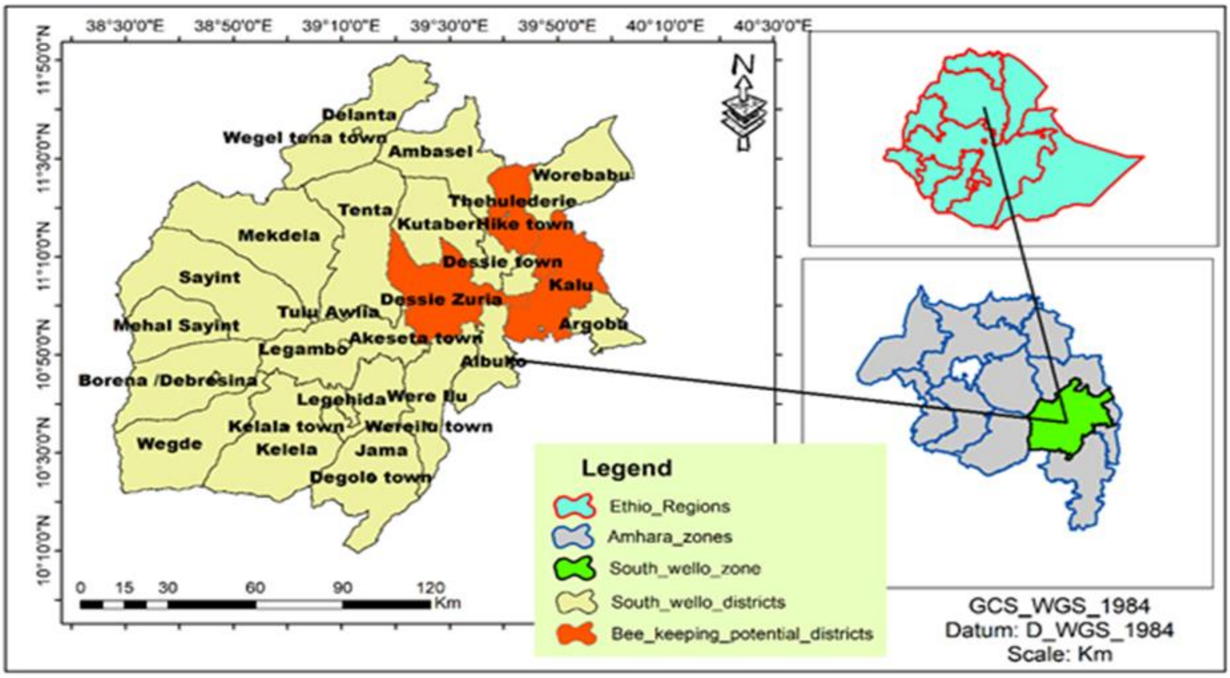

Fig. 1: Map of study area.

2.2. Data Collection Methods

A total of 90 colonies (30 colonies from each district (highland, midland and lowland) under on farm) were assigned to study the performance of honeybee colonies for reproductive swarming tendency, brood population, and nectar and pollen storage and honey yield. The performance of the colonies was evaluated from September to December 2021 and April to June 2022) during active season of the colony through the following parameters:

2.3. Evaluation of Reproductive and Productive Performance

Space (cm^2) covered by eggs, larvae, pupae, pollen, nectar and honey in the comb were measured using a frame sized transparent grid meter, which could fit well on the four wooden bars of the comb frames, when placed on it (Fig. 2). The grid consisted of squares each having 1cm^2 areas (Sena et al. 2012; Kumar et al. 2013). The grid was placed on the comb for measuring various parameters and numbers of squares of grid covering the different parameters were counted on all the combs in a colony every 21 days.

2.4. Evaluation of Swarming Behavior

Based on interviews and/or inspections for the development of queen cells, the reproductive swarming of the honeybee populations in the area was evaluated under the following circumstances. The proportion of reproductively swarmed colonies to the total number of colonies owned by interview beekeepers was used to calculate the extent of reproductive swarming. According to the ratio of total colonies to newly built queen cells, swarming tendency was estimated. To prevent double counting, these cells that had been counted were eliminated right away. During the active season, swarming tendency was assessed at intervals of 9 days.

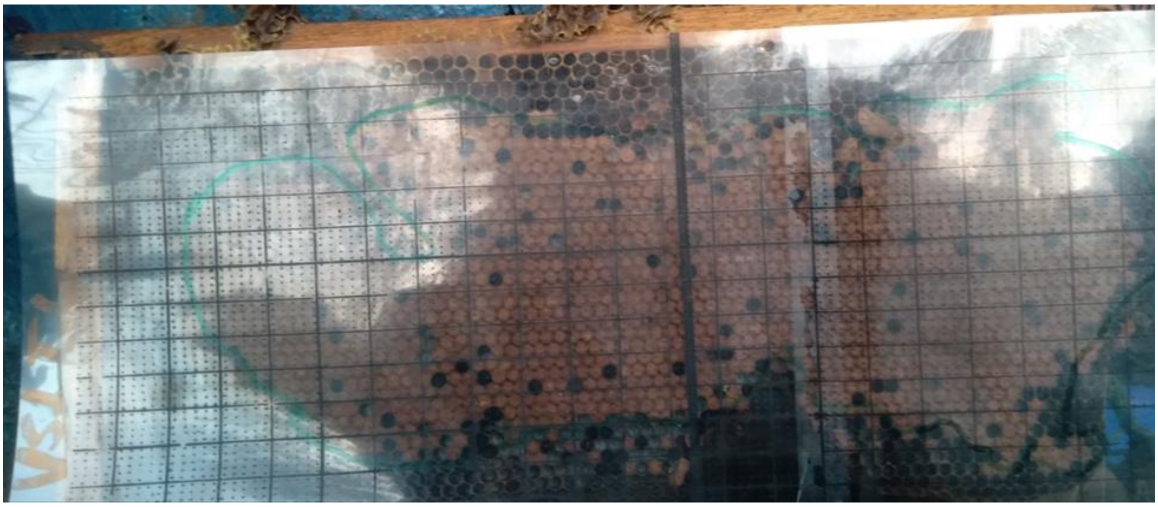

Fig. 2: Method of parameters measurement.

2.5. Honey Yield

First, frames with sealed honeycombs were removed from the hive, and each frame containing sealed honey was weighed in order to collect data on honey yield during the study period. The centrifugal honey extractor was then used to extract frames that contained honey. After the honey was extracted, empty frames were weighed. The weight after extraction was subtracted from the weight before the extraction to get the net honey yield (Mossie and Biratu 2019). The two main honey flow seasons in the research area are from October to November and June, respectively.

2.6. Data Analysis Methods

SAS's general linear model approach was used for dependent variables to find statistical differences between different types of beehives. As fixed independent variables, hive types were fitted. Tukey's studentized range test was used to compare means at $P \leq 0.05$.

Model used for the least - squares analysis of dependent variables was:

$Yij = \mu + hi + eij$

Where: Yijk = Observed dependent variables

μ = Overall mean

hi = Fixed effect of agro ecology/or districts (i=3; highland, midland, lowland)

eij = Residual error

3. RESULTS

Table 1 indicated overall brood area of different districts at the end of data collection. Dessie zuriya showed the highest Egg area (EA), Larvae area (LA) and Pupae area (PUA) (1343.8cm^2, 1407.05cm^2 and 1471.83cm^2) than Kalu (824.78cm^2, 874.57cm^2 and 926.10cm^2) and Tehuldere (519.25cm^2, 574.07cm^2 and 618.76cm^2) which had the lowest brood area respectively. There was statistical difference ($P<0.05$) between agro ecologies for measurements of all brood parameters.

Table 1: Brood areas (cm^2) of colonies in the study area of different agro ecology

District	Egg Area	Larvae Area	Pupae Area
Kalu(L)	824.78±29.80^b	874.57±30.60^b	926.10±31.45^b
Dessie zuriya(H)	1343.80±47.49^a	1407.05±47.89^a	1471.83±48.71^a
Tehuledere(M)	519.25±18.61^c	574.07±21.33^c	618.76±22.97^c
P-value	<0.0001	<0.0001	<0.0001

L: Lowland; H: Highland; M: Midland. $^{a-c}$ Means with different superscripts across a column are statistically significant.

Overall results of Pollen, nectar, honey area and honey yield of study districts (agro ecologies) was presented in Table 2. All above parameters Pollen area (POA), Nectar area (NA), Honey area (HA) and Honey yield (HY) were maximum in Dessie zuriya district (15.28cm^2, 343.17cm^2, 386.13cm^2 and 22.13cm^2) followed by Kalu (8.97cm^2, 201.15cm^2, 236.02cm^2 and 18.88cm^2) and Tehuledere (6.01cm^2 142.54cm^2, 150.39cm^2 and 12.83cm^2). There was significant difference between agro ecologies ($P<0.05$) in all these parameters.

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ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
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Table 2: Pollen, nectar and honey area (cm²) and honey yield (kg) of the study area in different agro ecology

District	Pollen Area	Nectar Area	Honey Area	Honey Yield
Kalu(L)	8.97±0.25[b]	201.15±8.40[b]	236.02±9.50[b]	18.88±0.70[b]
Dessie zuriya(H)	15.28±0.44[a]	343.17±15.17[a]	386.13±17.98[a]	22.13±0.88[a]
Tehuledere(M)	6.01±0.22[c]	142.54±6.83[c]	150.39±8.53[c]	12.83±0.62[c]
P-value	<0.0001	<0.0001	<0.0001	<0.0001

L: Lowland; H: Highland; M: Midland. [a-d] Means with different superscripts across a column are statistically significant.

Table 3: Swarming extent and swarming tendency of colonies in the study area in different agro ecology.

District	Swcol	Exrsw	Qcc	swate
Kalu (L)	2.57±0.61[a]	8.57±2.03[a]	4.43±0.95[a]	14.76±3.17[a]
Dessie zuriya(H)	2.14±0.53[ba]	7.14±1.77[ba]	4.29±0.92[a]	14.29±3.07[a]
Tehuledere (M)	0.71±0.25[b]	2.38±0.86[b]	2.00±0.62[a]	6.67±2.08[a]
P-value	0.0251	0.0251	0.0829	0.0829

Swcol: swarmed colony; exrsw: extent of swarming; qcc: queen cell construction; swate: swarmed tendency; L: Lowland; H: Highland; M: Midland. [a-d] Means with different superscripts across a column are statistically significant.

Overall swarming tendency of study area was indicated by Table 3. Swarmed colony (Swcol) and Extent of swarming (exrsw) were showed significance difference ($P<0.05$) with higher value in kalu (2.57cm^2 and 8.57cm^2) and lower in Tehuledere (0.71cm^2 and 2.38cm^2) but Dessie zuriya (2.14cm^2 and 7.14cm^2) was not statistically differ ($P>0.05$) with both Kalu and Tehuledere. Queen cell construction (Qcc) and Swarmed tendency (swate) was not affected by agro ecology ($P>0.05$). It was 4.43cm^2 and 14.76cm^2 for Kalu, 4.29cm^2 and 14.29cm^2 for Dessie zuriya and 2.00cm^2 and 6.67cm^2 for Tehuledere respectively.

4. DISCUSSION

With regard to colonies with different agro-ecological records, the Dessie Zuriya (highland) colony in the current study had the largest brood area, followed by Kalu (lowland) and Tehuledere (midland). The current study's brood area was 1343.8cm^2, 1407.1cm^2, and 1471.8cm^2 for eggs, larvae, and pupae, respectively. When compared with the results of Alemu et al. (2014) findings, which evaluated colonies of *A.m. Scutellata* and reported a total brood area of 216cm^2, Mossie and Biratu (2019) findings for *A.m. bandansii* reported a total brood area of 252.5cm^2. As well as this, Negash and Argaw (2022) reported 148cm^2 for *A.m. scutellata*, Aleme et al. (2017) reported unsealed brood area of 127cm^2 and sealed brood area of 94cm^2 for *A,m. wayi Gambela*.

Tarekegn et al. (2022) reported unsealed (54cm^2) and sealed (127cm^2) for *A.m. scutellata*. All of the aforementioned findings were lower than the outcome of the current study. However findings of Hunde and Hora (2022) on *A.m. bandansii* found brood area of 6114.1cm^2 and Meressa et al. (2016) on *A.m. monticolla* found unsealed brood area of 20.4cm^2 and sealed 2546.1cm^2 were higher than the result of the current study even though, the unsealed brood area lower than the current. The maximum brood raising was seen during the active season, which could be due to the region's abundance of honeybee flora, which ranges from weeds to forest trees and provides enough nutrition for bees during this month. *Apis mellifera* bees in tropical areas raise brood all year but lower the number reared during the rainy season (Tarekegn et al. 2022).

Many factors have been identified as contributing to the decline of honey bee colonies, such as pesticides, diseases, pathogens, commercial pollination methods, and environmental change (Asrat et al. 2023; Khushdeep et al. 2023; Nicole et al. 2023). A dangerous external parasite called Varroa is responsible for a number of problems for beekeepers, including declining adult numbers, stunted growth in young bees, erratic brood patterns, growth of disease-causing pathogens, adult bee departure from the hive, low honey productivity, and colony losses at an advanced stage (Yashdeep et al. 2023).

Weather parameters contribute major role in influencing the brood rearing, pollen area, nectar area, bee strength and honey production as well as the activity of pollen foragers (Manoj et al. 2017). The bee's activity and production rate are determined by the temperature conditions in its surroundings (Nazlı et al. 2023). One of the most significant elements influencing beekeeping and honey bees is temperature. Determining the ideal temperature is one of the most crucial steps toward making beekeeping and its products economically viable (Filmon, 2023; Krystyna et al. 2023; Rafael et al. 2023). Colony performance were impacted by beehive type and honeybee race (Abou-Shaara et al. 2013). According to Alqarni et al. (2014), pollen harvesting was impacted by solar radiation, but brood rearing activities was connected with monthly pollen storage. Based on climatic conditions, vegetation cover, altitude and other abiotic and biotic factors, honeybee races are dispersed throughout the nation for each region's agro ecologies (Aleme and Nwankwo 2021). According to Shumkova and Balkanska (2020), it is anticipated that foods like *Apimix* and *Apipasta*, which are high in vitamins and amino acids, will encourage bee colonies to produce more bee larvae. The amount of harvested and transmitted bee pollen in the hives increases as a result, strengthening the bee colonies. Pollen contains nutrients such proteins, minerals, vitamins, and lipids that are crucial for adult longevity, brood development, and colony growth (Abou-Shaara 2014; Arien et al. 2015; Aleme et al. 2017; Topal et al. 2022; Negash and Argaw 2022).

The current study's measurements of pollen, nectar, and honey area, which were strongly influenced by the agro-ecology of the study's subjects. The current study measured amounts of pollen, nectar, and honey of 15.3cm^2, 343.2cm^2, and 386.1cm^2, respectively. It showed lower value of pollen and higher value of nectar and honey than results reported by Alemu et al. (2014) showed 29.3cm^2 and 65.6cm^2 of pollen and nectar respectively for *A.m.scutellata* and (Aleme et al. 2017) reported 63cm^2, 32cm^2 and 144cm^2 of pollen nectar and honey area for *A.m. wayi gambela* respectively as well as Negash and Argaw (2022) who found 97.5cm^2 and 131.9cm^2 of pollen and nectar for *A.m.scutellata* respectively. In addition, result of Meressa et al. (2016) for *A.m. monticolla* was 24.4cm^2 and 254cm^2 of pollen and nectar respectively which was also higher in pollen but lower in nectar area. In comparison to the present study, Tarekegn et al. (2022) reported that the pollen area (2cm^2) and nectar area (35cm^2) of *A.m. scutellata* were lower. However, Hunde and Hora (2022) results from which reported 487cm^2 and 3399cm^2 of pollen and nectar for *A.m. bandansii,* respectively, were higher in both pollen and nectar.

Foraging activity by honeybee colonies depends on gathering pollen, nectar, honey, and its yield (Hristov et al. 2020). The main tendency of nectar and pollen storage activity does, in fact, coincide with the pattern of brood rearing of the investigated colonies in both agro-ecologies, it was further validated. The distance of honeybee forages, colony size, food availability, month, and time of day may all play a role in the difference between the active and dearth seasons of foraging activity. According to Topal et al. (2022), weather factors play a significant impact in regulating pollen foraging activity, pollen area, nectar area, bee strength, and honey output. Adult worker bees' metabolic processes are influenced by the nutritional quality of their larval meals, with diets that are better suited for survival having a greater metabolic rate per unit of body mass (Crone and Grozinger 2021).

Like all living things, honeybees require a balanced and sufficient diet. Reduced immunity, more stress, a shorter life span, and colony loss can all result from malnutrition. In order for brooding behaviors to continue and for the colony's young population to grow, pollen is required (Divya et al. 2017; Hoover et al. 2022). According to Sihag and Kaur (2018), there is mounting proof that high-quality nutrition can reduce the negative effects of several stresses on honeybees (*Apis mellifera*). For the development of more resilient phenotypes, pollen, the main source of protein and fats in bee diets, is particularly important. Beehive type and honeybee race have an impact on colony performance (Abou-Shaara et al. 2013).

According to Manoj et al. (2017), diet is one element that influences how much nectar is present in honeybee colonies' hives. According to El-Wahab (2016) and Gabka (2014), colony strength has an impact on the pollen, nectar, and honey areas. Pollen and nectar stores were also identified by Shehata (2016), Saini et al. (2018) and Tawfik et al. (2020) as being positively correlated with brood and colony strength. The principal honey harvesting season of the year, which runs from October to November, saw larger honey yields than usual.

This could be attributed to the abundance of food supplies, which may have a significant impact on the health and productivity of honeybee colonies. The mean honey output (kg) per harvest per hive for this race was higher than the race found in the upland area. The higher honey yield was recorded during the primary honey harvesting season of the year from October to December and this might be due to the abundant availability of forage sources that could profoundly impact honeybee colony strength and productivity. The maximum honey yield of the present study was 22.2kg which was higher than the range of the national level (19.1kg). For the *A.m bandansii*, Mossie and Biratu (2019), reported a maximum honey yield of 12.33kg.

In addition, Zewdu (2012) for *A.m. Bandansii* found 12.5kg, Hunde and Hora (2022) found 11.8kg for *A.m. scutellata* and Meressa et al. (2016) reported 18.2kg for *A.m. monticolla*, all of which were lower results than the current finding. 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 (Mossie and Biratu 2019; Islam et al. 2020; Tawfik et al. 2020). According to Büchler et al. (2013) and Delaplane et al. (2013), all of the colonies' unsealed/sealed brood, pollen, and honey supplies, as well as colony strength, environmental conditions and beekeeping management practices were highly and significantly correlated.

The greatest reproductive swarming season for *A.m. monticolla* occurred between October-December. This is likely because these months coincided with periods of peak plant blossoming, which provided a surplus of bee forages. These months represent the honeybees' active season in the research area. Due to repeated queen cell growth and advanced markers of swarm preparation, the race produced more queen caps per hive in October, demonstrating a strong desire to swarm. These findings are consistent with earlier studies that found tropical honeybees typically have a high want to reproduce by swarming and a propensity to rapidly increase population, which leads in the rapid multiplication of colonies (Hunde and Hora, 2022; Tarekegn et al. 2022). A study based on months also indicates that 60% of *A. m. monticolla* colonies' peak swarming period is in October-December (Meressa et al. 2016). The variation among these reports might be due to the agro-ecological difference in the study areas. The expression of these behavioral traits can be strongly influenced by environmental factors and beekeeping management techniques (Büchler et al. 2013; Delaplane et al. 2013).

The swarming tendency in the current study was not affected by agro-ecology. And recorded amaximum of (4.4) queen cells. This result was higher than findings of Tarekegn et al. (2022) who reported 3.42 for *A.m. scutellata*, Hunde and Hora (2022) who reported 2.2 for *A.m. bandansii*, Alemu et al. (2014) who reported 2 for *A.m. scutellata* and Uzunov et al. (2014) who found 2.44. However, it was lower than the findings reported by Meressa et al. (2016) which was (30) on *A. m. monticolla* and, and by Negash and Argaw (2022) who found (5.2) for *A. m. Scutllata.*

5. CONCLUSION

This study showed that compared to other ecotypes and races in the country, honeybee colonies in the study area generally performed better in terms of both productive and reproductive aspects. In this study, colonies located in the zone's highland performed better than colonies located in the study area's midland and lowland. Of course, a crucial job for future research programs will be to assess how well these various ecotypes perform outside of their specific niches. Finally, we urge placing more focus in the future on choosing the colonies that do the best.

Declaration of Competing Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability: Data will be made available on request.

Acknowledgment: We would also like to thank my Advisors, Injibara University, Wollo University and South Wollo Agricultural office and Developmental Agents of each district for their assistance during this research study.

Author's Contributions: Wubalem Alebachew: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft. Prof. Berhan Tamir: Supervision, Methodology, Visualization, Writing - review editing and validation. Dr. Tadesse Amare: Supervision, Methodology, Visualization, Writing - review editing and validation Dr. Amsalu Bezabih: Supervision, Methodology, Visualization, Writing - review editing and validation.

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REFERENCES

Abou-Shaara HF, 2014. The foraging behaviour of honeybees, Apis mellifera: A review. Veterinarni Medicina 59(1), 1–10. https://doi.org/10.17221/7240-VETMED

Abou-Shaara HF, Al-Ghamdi AA and Mohamed AA, 2013. Honeybee colonies performance enhance by newly modified beehives. Journal of Apicultural Science 57(2), 45–57. https://doi.org/10.2478/jas-2013-0016

Aleme M and Nwankwo C, 2021. Performance of various Honeybee Races: A Review. International Journal of Agriculture and Biosciences 10(1): 51–54.

Aleme M, Yadessa E, Tulu D, Bogale A, Mengistu G and Bezabeh A, 2017. Performance Evaluation of Local Honeybee Races (Apismellifera Wayi Gambella) in Sheka Zone. International Journal of Research in Agricultural Sciences 4(6), 282–287.

Alemu T, Legesse G and Ararso Z, 2014. Performance Evaluation of Honeybee (Apis mellifera scutellata) in Guji Zone. International Journal of Innovation and Applied Studies 9(4), 1987–1993.

Alqarni AS, Balhareth HM and Owayss AA, 2014. Performance evaluation of indigenous and exotic honeybee (Apis mellifera L.) races in Assir region, southwestern Saudi Arabia. Saudi Journal of Biological Sciences 21(3), 256–264. https://doi.org/10.1016/j.sjbs.2013.10.007

Anthony D Vaudo, James D Ellis, Garth C and Martin H, 2012. The effects of land use on honeybee (Apis mellifera) population density and colony strength parameters in the Eastern Cape , South Africa The effects of land use on honeybee (Apis mellifera) population density and colony strength parameters in the E. Journal Insect Conservation 16: 601–611. https://doi.org/10.1007/s10841-011-9445-0

Arien Y, Dag A, Zarchin S, Masci T and Shafir S, 2015. Omega-3 deficiency impairs honeybee learning. Pnas 112(51), 15761–15766. https://doi.org/10.1073/pnas.1517375112

Asrat D, Markos F and Dereje A (2023). Causes of Honeybee Colony Decline in South Ethiopia. Online Journal of Animal and Feed Research 13(4):259-268.

Bihonegn A, Begna D, Tassew A, Zeleke A and Mekuriaw, 2017. Physicochemical properties of Ethiopian Beeswax, the case of South Wollo zone, Amhara Region. International Journal of Agricultural Science and Food Technology 061–066. https://doi.org/10.17352/2455-815x.000024

Büchler R, Andonov S, Bienefeld K, Costa C, Hatjina F, Kezic N, Kryger P, Spivak M, Uzunov A and Wilde J, 2013. Standard methods for rearing and selection of Apis mellifera queens. Journal of Apicultural Research 52(1). https://doi.org/10.3896/IBRA.1.52.1.07
Crone MK and Grozinger CM, 2021. Pollen protein and lipid content influence resilience to insecticides in honeybees (Apis mellifera) . Journal of Experimental Biology 224(9). https://doi.org/10.1242/jeb.242040
Delaplane KS, van der Steen J and Guzman-Novoa E, 2013. Standard methods for estimating strength parameters of Apis mellifera colonies. Journal of Apicultural Research 52(1). https://doi.org/10.3896/ibra/1.52.1.03
Divya C, Devinder S, Suheel AG, Thanlass N and Seeley S, 2017. Effect of colony strength on colony build up and foraging activity of Apis mellifera L. Journal of Entomology and Zoology Studies 5(6), 1369–1373.
El-Wahab A, 2016. Assessment a New Pollen Supplement Diet for Honeybee Colonies and Their Effects on some Biological Activities. International Journal of Agricultural Technology 12(1), 55–62.
Filmon H, 2023. Market value chain of honey production in Northern Ethiopia. African Journal of Agricultural Research 19(11):1019-1031. https://doi.org/10.5897/AJAR2023.16485
Gabka J, 2014. Correlations between the strength , amount of brood , and honey production of the honeybee colony. Med Weter 70(12), 754–756.
Hoover SE, Ovinge LP and Kearns JD, 2022. Consumption of Supplemental Spring Protein Feeds by Western Honeybee (Hymenoptera: Apidae) Colonies: Effects on Colony Growth and Pollination Potential. Journal of Economic Entomology 115(2), 417–429. https://doi.org/10.1093/jee/toac006
Hristov P, Shumkova R, Palova N and Neov B, 2020. Factors associated with honeybee colony losses: A mini-review. Veterinary Sciences 7(4), 1–16. https://doi.org/10.3390/vetsci7040166
Hunde T and Hora Z, 2022. Determining the Performance of Apis Mellifera Bandasii Populations under Different Agro-Ecologies of Central Ethiopia. Advances in Agriculture 2022, 6. https://doi.org/10.1155/2022/2591154
Islam N, Mahmood R, Sarwar G, Ahmad S and Abid S, 2020. Development of Pollen Substitute Diets forApis mellifera ligustica Colonies and their Impact on Brood Development and Honey Production. Pakistan Journal of Agricultural Research 33(2), 381–388.
Khushdeep D, Rakesh R and Manveer S, 2023. Production and Marketing of Honey Prospects and Constraints- A Review. Biological Forum – An International Journal 15(8a): 407-413.
Krystyna C, Sylwia Ł and Stanisław M, 2023. The effect of meteorological and environmental variables on food collection by honey bees (Apis mellifera). Ecological Indicators 156: 111-140.
Kumar S, Kumar P, Sharma TK and Pant M, 2013. Bi-level thresholding using PSO, artificial bee colony and MRLDE embedded with Otsu method. Memetic Computing 5: 323-334. https://doi.org/10.1007/s12293-013-0123-5
Manoj KP, Shaw SS, Thakuar R and Yogeth N, 2017. Influence of Weather Parameters on Colonies Performance Parameters of Indian Bee, Apis cerena indica. International Journal of Current Microbiology and Applied Sciences 6(11), 2375–2380. https://doi.org/10.20546/ijcmas.2017.611.281
Margaret KW, Heather RM and Thomas S, 2011. Collective personalities in honeybee colonies are linked to colony fi tness. Animal Behaviour 81(3), 559–568. https://doi.org/10.1016/j.anbehav.2010.11.027
Meixner MD, Hessen LL, Pinto MA, Bouga M and Kryger P, 2013. Standard methods for characterising subspecies and ecotypes of Apis mellifera Standard methods for characterising subspecies and ecotypes of Apis mellifera Métodos estándar para la caracterización de las subespecies y ecotipos de Apis mellifera. Journal of Apicultural Research 52(4). https://doi.org/10.3896/IBRA.1.52.4.05
Mossie T and Biratu K, 2019. Performance Evaluation of Local Honeybee Races Under in- Situ and Ex-Situ Agro-Ecological Zones of Ethiopia. Academic Journal of Entomology 12, 12(1), 9–13. https://doi.org/10.5829/idosi.aje.2019.09.13
Meressa L, Abebe J, Addisu B, Alemu T, Ayalew G and Adane, 2016. Performance Evaluation of the Local Honeybee Race (Apis mellifera monticolla) of the Amhara Region in Wag-himra zone, Ethiopia. Proceeding the 9th Annual Regional Conference on Completed Livestock Research.
Nazlı P, Muzaffer D, Ümit K, Fatih Y Hasan F and Belgin G, 2023. The effects of altitude and rearing period on some characteristics of honey bee queens, Apis mellifera caucasica Gorbachev, 1916 (Hymenoptera: Apidae). Türk Entomology Derg 47 (3): 295-306. http://dx.doi.org/10.16970/entoted.1207868
Negash D and Argaw A, 2022. On station performance evaluation of local honeybee colonies traits (Apis mellifera scutellata) in Gedeo zone, Ethiopia. International Journal of Veterinary Sciences and Animal Husbandry 7(4), 46–50. https://doi.org/10.22271/veterinary.2022.v7.i4a.431
Nicole SD, Jon FH and Brian HS, 2023. The effects of anthropogenic toxins on honey bee learning: Research trends and significance. Apidologie 54: 59. https://doi.org/10.1007/s13592-023-01040-w
Rafael L, Rodriguez M and Parrella J, 2023. Honey Production and Climate Change: Beekeepers' Perceptions, Farm Adaptation Strategies, and Information Needs. Insects 14, 493. https:// doi.org/10.3390/insects14060493
Saini S, Chaudhary OP and Anoosha V, 2018. Relationship of population size and extraction frequency with honey production in Apis mellifera colonies. Journal of Entomology and Zoology Studies 6(3), 1374–1377
Sena L, Sena S and Hoda A, 2012. Feeding Efficiency of Pollen Substitutes in a Honeybee Colony. Agricultural and food science. Corpus ID: 86257502
Shehata IAA, 2016. Evaluation of Carniolan and Italian Honeybee Colonies Fed on Artificial Diets in Dearth and Flowering Periods under Nasr City Conditions. International Journal of Environment 05(02), 19–25
Shumkova R and Balkanska R, 2020. Apimix and Apipasta the New Trend in Bee Feeding and Creation of New Bee Colonies. Iranian Journal of Applied Animal Science 10(4), 755–762

Sihag RC and Kaur G, 2018. Patterns of short and long-term responses of honeybee (Apis mellifera L .) colony to changes in its internal environment. Journal of Ecology and The Natural Environment 10(6), 108–128. https://doi.org/10.5897/JENE2017.0679
Tarekegn A, Mulisa F, Faji M. and Alemayehu A, 2022. Swarming and Foraging Behavior of Apis mellifera scutellata bee race. https://doi.org/https://doi.org/10.21203/rs.3.rs-1743077/v3
Tawfik AI, Ahmed ZH, Abdel-Rahman MF and Moustafa AM, 2020. Influence of winter feeding on colony development and the antioxidant system of the honeybee, Apis mellifera. Journal of Apicultural Research 59(5), 752–763. https://doi.org/10.1080/00218839.2020.1752456
Topal E, Mărgăoan R, Bay V, Takma Ç, Yücel B, Oskay D, Düz G, Acar S and Kösoğlu M, 2022. The Effect of Supplementary Feeding with Different Pollens in Autumn on Colony Development under Natural Environment and In Vitro Lifespan of Honeybees. Insects 13(7), 588. https://doi.org/10.3390/insects13070588
Topal E, Rodica M and Bay V, 2022. The Effect of Supplementary Feeding with Different Pollens in Autumn on Colony Development under Natural Environment and In Vitro Lifespan of Honeybees. Insects 13, 588. https://doi.org/org/10.3390/insects13070588
Uzunov A, Costa C, Panasiuk B, Meixner M, Kryger P, Hatjina F, Bouga M, Andonov S, Bienkowska M, Conte YL and Wilde J, 2014. Swarming, defensive and hygienic behaviour in honey bee colonies of different genetic origin in a pan-European experiment. Journal of Apicultural Research 53(2): 248-260.
Yashdeep K, Ayush K, Dharineesh, Siddharth S, Nikhil C, Sneha B and Gharde S, 2023. Effect of Environmental Stresses on Honeybee Population. International Journal of Environment and Climate Change 13(8): 2087-2096
Zewdu A, 2012. Study on productivity and behavioral aspects of local honeybee (Apis Mellifera bandasii), In: Apicultural Research achievement in Ethiopia. Collection of abstracts. Oromia Agricultural Research Institute, Holeta Bee Research Center, 2012, Holeta, Ethiopia.

Citation: Alebachew W, Tamir B, Amare T and Bezabh A, 2024. Evaluation of productive and reproductive performance of honeybee colonies (*Apis mellifera monticolla*) in South Wollo, Amhara, Ethiopia. Agrobiological Records 16: 49-56. https://doi.org/10.47278/journal.abr/2024.011