Citation/Atıf: Tarekegn A, Faji M, Abebe A. Production performance and various important behaviors performed by the A*pis mellifera scutellata* bee race (Üretim performansı ve Apis mellifera scutellata arı irkı tarafından gerçekleştirilen çeşitli önemli davranışlar). U. Arı D. / U. Bee J. 2022, 22(2):211-226. DOI: 10.31467/uluaricilik.1181552

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

PRODUCTION PERFORMANCE AND VARIOUS IMPORTANT BEHAVIORS PERFORMED BY THE *Apis mellifera scutellata* BEE RACE

Üretim Performansı ve *Apis mellifera scutellata* Arı Irkı Tarafından Gerçekleştirilen Çeşitli Önemli Davranışlar

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Geliş Tarihi / Received: 29.09.2022 Kabul Tarihi / Accepted: 21.10.2022 DOI: 10.31467/uluaricilik.1181552

ABSTRACT

Honey bee colonies exhibit a wide range of behavioral variations depending on genetic origin and environmental factors. Therefore, the performance evaluation of honey bee races is critical to laying a foundation for future selection and improvement in Ethiopia. Thirty colonies of Apis mellifera scutellata (A. m. scutellata) similar in resources contained in the hive were kept in improved box hives and evaluated through various behaviors (i.e. Reproductive swarming tendency, foraging activity, defensive behavior, hygienic behavior, brood population, honey production, and absconding behavior) during the active season and dearth season. In the study area, the A. m. scutellata race has a higher swarming tendency in the active season, with up to 3.42 queen caps per hive prepared per year. Defensive behavior during the active season takes an average of 25.41 seconds after disturbances and follows up to a 212.20-meter distance. But during the dearth season, the colony slightly took a long time to reach aggressiveness after disturbance (31.28 seconds) and followed the observer for a short distance (45.58 meters). The closed brood production is higher (149 units per hive) during the active season and nectar production units per hive are reduced by 50% as compared to the dearth season. The yielding performance of the race per frame ranged from 1.3 kg to 1.5 kg, and an average of 14 kg of honey per harvest. The A. m. scutellata exhibited an absconding tendency of 34.5% if there was any disruption. A. m. scutellata showed good performance in hygienic behaviors (>95%), but undesirable behaviors in defensive behavior, and swarming tendencies make it difficult to manage honey bees. However, the race has good performance in foraging and hygienic behaviors. Further, studies of the honey bee race through selection and breeding could be conducted to reduce the higher defensive and swarming tendency of A. m. scutellata to improve production performance.

Keywords: A. m. scutellata, Honey yield, Hygiene, Absconding, Aggressiveness

ÖZ

Bal arısı kolonileri, genetik kökene ve çevresel faktörlere bağlı olarak çok çeşitli davranış farklılıkları sergiler. Bu nedenle, bal arısı ırklarının performans değerlendirmesi, Etiyopya'da gelecekteki seçim ve iyileştirme için bir temel oluşturmak için kritik öneme sahiptir. Kovanda bulunan kaynaklara benzer

otuz *Apis mellifera scutellata* kolonisi geliştirilmiş kutu kovanlarda tutuldu ve aktif mevsim ve kıtlık mevsimi boyunca çeşitli davranışlarla değerlendirildi (örn; üreme, oğul eğilimi, yayılma davranışı, savunma, hijyenik davranış, yavru ve bal üretimi ve kovan terk). İnceleme alanında *A. m. scutellata* ırkı, aktif sezonda, kovan başına yılda 3,42 ana yüksüğü hazırlamasıyla, daha yüksek bir oğul verme eğilimine sahiptir. Aktif sezonda savunma davranışı, rahatsızlıklardan sonra ortalama 25.41 saniye sürüyor ve 212.20 metrelik bir mesafeyi takip etmektedir. Ancak kıtlık mevsiminde, koloninin rahatsızlıktan sonra saldırganlığa ulaşması biraz uzun sürmekte (31.28 saniye) ve gözlemciyi kısa bir mesafe (45.58 metre) takip etmektedir. Aktif sezonda kapalı kuluçka üretimi daha yüksektir (kovan başına 149 ünite) ve kovan başına nektar üretimi kıtlık dönemine göre %50 azalmıştır. Çerçeve başına verim performansı 1,3 kg ile 1,5 kg arasında değişmekte ve hasat başına ortalama 14 kg bal alınmıştır. *A. m. scutellata*, herhangi bir rahatsızlık olması durumunda %34.5'lik bir kaçma eğilimi sergilemektedir. Bunun yanında hijyenik davranışlarda iyi performans göstermekte (>%95), ancak savunma davranışında istenmeyen davranışlar ve oğul verme eğilimleri bal arılarını yönetmeyi zorlaştırmaktadır. Bununla birlikte, ırk, yayılma ve hijyenik davranışlarda iyi bir performansa sahiptir. Ayrıca, gelecekte seleksiyon ve ıslah çalışmaları ile savunma ve oğul verme eğilimi azaltılarak üretim performansını artırılabilir.

Anahtar Kelimeler: *A. m. scutellata*, Bal verimi, Hijyen, Kaçma, Saldırganlık

GENIŞLETILMIŞ ÖZET

Amaç: Bu çalışma *A. m.scutellata*'nın performansını belirlemeyi amaçlamıştır.

Gereç ve Yöntem: Bu çalışma, Etiyopya'nın batısındaki Assosa Tarımsal Araştırma Merkezi'ndeki Benishangul Gumuz bölgesel eyaletinde gerçekleştirildi. Assosa kasabası, Etiyopya'nın Addis Ababa kentinin 670 km batısında yer almaktadır. Benishangul Gumuz bölgesi deniz seviyesinden 1272 ila 1573 metre yükseklikte değişen 10° 38' 20.45" K enlem ve 35° 43' 58.92" Doğu boylam coğrafi koordinatları arasında yer almaktadır.

Benzer kaynaklara sahip otuz *Apis mellifera scutellata* kolonisi geliştirilmiş kutu kovanlarda tutuldu ve aktif mevsim ve kıtlık mevsimi boyunca çeşitli davranışlarla değerlendirildi (örneğin; üreme, oğul eğilimi, yayılma faaliyetleri, savunma ve hijyenik davranış, yavru, bal üretimi ve kovan terk etme davranışı).

Bulgular: İnceleme alanında *A. m. scutellata* ırkı, aktif sezonda, kovan başına yılda 3,42 ana yüksüğü hazırlanmasıyla, daha yüksek bir oğul verme eğilimine sahiptir. Aktif sezonda savunma davranışı, rahatsızlıklardan sonra ortalama 25.41 saniye sürüyor ve 212.20 metrelik bir mesafeyi takip etmektedir. Ancak kıtlık mevsiminde, koloninin rahatsızlıktan sonra saldırganlığa ulaşması biraz uzun sürmekte (31.28 saniye) ve gözlemciyi kısa bir mesafe (45.58 metre) takip etmektedir. Aktif sezonda kapalı kuluçka üretimi daha yüksektir (kovan başına 149 adet) ve kovan başına nektar üretim ünitesi, kıtlık dönemine göre %50 azalmıştır. Çerçeve başına verim performansı 1,3 kg ile 1,5 kg arasında değişmekte ve hasat başına ortalama 14 kg bal alınmaktadır. *A. m. scutellata*, herhangi bir rahatsızlık olması durumunda %34.5'lik bir kovan terk etme eğilimi sergilemektedir. Bu ırk hijyenik davranışlarda iyi performans göstermekte (>%95), ancak savunma davranışında istenmeyen davranışlar ve oğul verme eğilimleri bal arılarında koloni yönetimini zorlaştırmaktadır. Bununla birlikte, ırk, yayılma ve hijyenik davranışlarda iyi bir performansa sahiptir. Ayrıca, bu ırkın üretim performansını artırmak için seçim ve ıslah çalışmaları ile yüksek savunma ve oğul eğilimi azaltılabilir.

Sonuç: Genel olarak, sonuçlarımız *A. m. scutellata* bal arısı kolonileri daha yüksek savunma ve kovan terk eğilimi gösterir. Bununla birlikte, ırk, yayılma ve hijyenik davranışlarda iyi bir performansa sahiptir. Bal arılarının oğul verme eğilimi yüksektir. Hazırlanan daha yüksek seviyede bir ana arı, tek bir koloniden sürülerin tekrarlanmasına yol açar. Gelecekteki araştırmalar, koloninin daha yüksek bir kovan terk etme oranını azaltmak için potansiyel etkileri ve yönetim uygulamalarını dikkate almalıdır. Ek olarak, *A. m.scutellata*'nın en iyi performans gösteren kolonisinin seçimi ve üremesi konusunda daha ileri çalışmalar yapılabilir. Ayrıca, araştırmacılar *A. m.scutellata*'nın yayılma davarnışı konusundaki verimliliğini de araştırmalıdır. Bu arı ırkının yayılmacı arıları yani toplayıcıların aktif ve kıtlık dönemlerinde bir besin kaynağına seyahat

etmek için ne kadar zaman harcadıkları, seyahat süresinin araştırılması gerekmektedir.

INTRODUCTION

Ethiopia is well-known for its wide range of agro-climatic conditions and biodiversity, which has supported the existence of diverse honeybee flora and a large number of beehive colonies (Adgaba 2007; Fichtl 1994). The country's diverse agroclimatic characteristics generate conducive environmental conditions for the cultivation of over 7000 species of flowering plants, the majority of which are bee plants (Fichtl 1994; Nuru et al. 2002). Ethiopia has the largest bee population in Africa, with over 10 million bee colonies, of which 5 to 7.5 million are estimated to be hived, with the remaining existing in the wild (Legesse 2014). The total annual beeswax production is estimated to be over 3,800 tons. With this quantity, the country ranks fourth in the world in beeswax production. Furthermore, Ethiopia can generate up to 500,000 tons of honey and 50,000 tons of beeswax per year (CSA 2006).

In Ethiopia, despite the potential of apicultural resources, production and productivity are relatively low. This could be attributed to many factors such as the way of management, the environment, and the race of honey bees. It is known that the physical environment (season, altitude, vegetation, climate, etc.) dramatically affects the behavior and productivity of honey bee colonies (Mossie 2019). In addition, honeybee colonies do not perform equally even under the same environmental conditions and managerial practices (Al-Ghamdi et al. 2017). Honeybee colonies' performance (strength and productivity) is determined by the total area of comb in the colony, which contains stored honey, pollen, and brood, the adult bee population, weight per bee, and the colony nest cavity volume ratio (Vaudo et al. 2012). In addition to this, the most important that determines the survival and development of the colonies is the combined behaviors of individual honey bees including nest-building, foraging, temperature regulation, hygiene, and defense (Siefert et al. 2021). Those behaviors like foraging are affected by the experience, wing damage, environmental factors, and internal conditions of the colonies (Klein et al. 2019). Colony defense, which includes recognizing predators, alerting nest mates, and enacting anti-predator behavior, is a well-known type of behavior in honey bees (Breed et al. 2004). Swarming and colony defense have long been recognized by beekeepers, who have used breeding strategies to reduce their expression in defiance of natural selection (Kovačić et al. 2020). For example, swarming is the natural way for honey bee colonies to reproduce, and this behavior is thus closely linked to fitness; however, beekeepers prefer colonies that never swarm. Moreover, the defensive behavior is also frowned upon by beekeepers, but even the most docile honey bee colonies can fall prey to natural enemies such as wasps, birds, or mammals (Ilyasov et al. 2015). Recent research has focused on behaviors related to colony health and disease control, such as hygienic behavior and grooming (Spivak and Danka 2021). The expression of these behavioral traits can be strongly influenced by environmental factors and beekeeping management techniques (Bigio et al. 2013). Nonetheless, they are known to differ in distinctive ways among the many honey bee subspecies and populations that have been scientifically described to date (Ruttner 1988). Indeed, the honey bees of Ethiopia form a population of their own that is distinct and well separated from the honey bees of Africa (Meixner et al. 2011). The variations include all the desired and undesired traits in production, productivity, and behavior. Study shows that in Ethiopia, small lowland honeybees are very aggressive and more productive than honeybees of the highland areas larger in size, docile in behavior, and less productive (Chala et al. 2013). Consequently, *A. m. scutellata* is one of the honey bee races found in the lowlands of Ethiopia (Amssalu et al. 2004)

In east Africa, *A. m. scutellata* is found from 500–2400 meters, in rich savannah and semi-evergreen deciduous forests (Smith 1961). In Ethiopia, the *A. m. scutellata* is distributed in the western humid mid-land parts, including southwestern parts of Gojjam (around Bir Sheleko and Chagni), all areas of Wollega, west of Nekemte and Shambu up to Assosa and Dembidolo (Mohammed 2002). The continuous distribution of this group was also observed in similar ecological areas in southwest parts of Ethiopia in places like Gecha and Masha (Amssalu 2002). The *A. m. scutellata* colony found in the area shows highly aggressive behavior and other undesirable behaviors constraint for the beekeeping sectors.

Good quality stocks must be established in apiaries, then multiplied and maintained to reap the benefits of beekeeping. As a result, evaluating the performance of the *A. m. scutellata* race is essential for future selection and improvement. However, no research on *A. m. scutellata*'s performance in Ethiopia has been conducted. So, this study aimed to determine the performance of *A. m. scutellata* honey bee races in the study area.

MATERIALS AND METHODS

Study Area

The study was conducted in Benishangul Gumuz regional state in Assosa Agricultural Research Center, western Ethiopia. Assosa town is located 670 km west of Addis Ababa, Ethiopia. Benishangul Gumuz regional state is situated between geographical coordinates: 10° 38' 20.45" N latitude and 35° 43' 58.92" E longitude with altitudes ranging from 1272 to 1573 meters above sea level. The region's mean annual rainfall and temperature range between 700 to 1450 mm and 21 to 35°C, respectively. Major crops grown in the areas are sorghum, maize, finger millet, soya bean, and groundnut (AsARC, 2006, Unpublished).

Method of Data Collection

To start with the performance evaluation of the honey bee race at their original ecology, the A. m. scutellata honey bee race was identified at the well-established apiary site. At the Assosa Agricultural Research Center Apiary site, 30 colonies of equal performance and hive resources were kept and studied. These colonies were established in improved box hives and their difference in performance was evaluated through different parameters. Out of 30 colonies, five colonies were assigned to study honey production, and 25 honey bee colonies for reproductive swarming tendency (three colonies), foraging activity (nine colonies), defensive behavior (three colonies), hygienic behavior (seven colonies), brood population (three colonies), and absconding behavior (all experimental colonies). The colonies were separated for honey yield production and reproductive data collection, to avoid the effect of colony disturbance during the reproductive data collection on the yield of honey. The performance of the colonies was evaluated from September 2015 to January 2017 active season (October to December and April to May) and dearth season (July to August) of the colony through the following parameters:

Swarming behavior

Based on the geographical distribution of the swarming period of the race the data collection starts from October to November (Nuru et al. 2002). The swarming behavior was evaluated by counting queen cells at nine days intervals per hive during the active season (Büchler et al. 2013).

Foraging behavior

The foraging behavior of honeybees was assessed by counting the number of bees flying out of the hives for five minutes. The measure of the colony foraging activity was monitored by two observers visually at the hive entrance by limiting the observation time of the day with good flight conditions of the colony. At the time of data collection, the observers sit on the side of the colony to avoid obstructing the flight of the bees. Then each observer using a hand-held timer counted and recorded the exiting foragers bees per five minutes during the late foraging time of the day (Delaplane et al. 2013). Moreover, the commencement of early foraging and finishing time of late foraging were also recorded (Büchler et al. 2013). The time used to record was the east African time zone.

Defensive behavior

To measure the defensive behavior of the honey bee colony, a test of aggressiveness was used (Stort 1975). A 2 cm diameter black leather ball was jerked for 60 seconds at a distance of 5 cm in front of the entrance of a colony. The gloved hands of the observer were situated 1 meter above the leather ball. The right gloved hand was moved during the test because it is used to jerk the thread that moves the leather ball. The gloved left hand was not moving. Then when the first sting was made in the leather ball, the time taken for the colony to become very aggressive, the number of stings in the gloves of the observer, the number of stings in the leather ball, and the distance that the bees followed the observer data were collected. The number of stings left in the gloves worn by the observer has counted afterward. Each colony was tested five times with 10 minutes between tests at the active time of the day from 1:00 pm to 2:00 pm (Büchler et al. 2013).

Hygienic behavior

The colonies of *A. m. scutellata* were tested for hygienic behavior at apiary sites. The pin-killed brood test method was used. A comb with a good pattern of brood (Larvae and pupae) is taken and hundreds of the brood larvae and pupa were killed by a long needle. Then after 24 hours, the hygienic behavior of the colony was analyzed by counting the number of dead brood cells that the workers had already cleaned. The frame with a pin-killed brood was marked for easy identification during data collection. These tests were repeated three times at different times in the same colony. If a colony removes 95% of the dead brood on the first test but only 50% on the second, then the colony is not hygienic. The colonies were considered hygienic only if they removed >95% of the brood on two consecutive tests (Büchler et al. 2013). The speed with which a colony removed a dead brood is correlated with its ability to remove diseased and parasitized brood. Finally, the percent of removal of dead brood was calculated as follows the formula used by (Kebede 2006).

R= (K-E-c)/(T-E) x100

Where: R = Percent removal of dead brood within 24 hrs.

K = Number of dead brood removed within 24 hrs.

E = Number of empty cells within the section inserted before the test.

c = Number of brood cells remained capped after 24 hrs.

T = Total number of broods within the section of an insert.

Measurement of brood, pollen, and nectar area

The total brood area was measured every 21 days using a plastic frame by overlaying 10 x 10 and 5 × 5 cm and placed over each side of the brood combs. The total brood populations were expressed in units per hive from the total area occupied by the brood. In addition to this, the comb area occupied by pollen and nectar stores was measured in the same way (Büchler et al. 2013).

Honey yield

The data was recorded every harvesting season by weighing frames containing ripen/sealed honey before and after extraction and then expressed in kg per colony per year and an average yield of the *A. m. scutellata* race was determined (Büchler et al. 2013). The study area's major and minor honey flow season is October to November and April to May, respectively.

Absconding behavior

The absconding tendency was evaluated by the ratio of colonies evacuated to the number of colonies used for the experiment provided that all the colonies are kept under uniform environmental conditions and colony disturbance and feed deterioration of the hive were conducted (Büchler et al. 2013).

Data Analysis

Data collected were analyzed using R software 4.0.0. One-way analysis of variance (ANOVA) and descriptive statics were used and Duncan's new multiple range test at a 5% level of significance was used to make the mean separation whenever significant results were encountered.

RESULTS

Swarming Tendency

The swarming tendency of the *A. m. scutellata* at the time of the active season is indicated in Table 1. The result showed that at the time of active season the number of queen cells prepared for swarming was significantly (p<0.001) different at the time of observation (months). Across the experimental years, a higher number of queen caps per hive was produced in October (active season). During this season the colonies swarm more than 1 time and no honey production from the colony in the study area. The observation also indicates queen cells prepared in the first and second higher (p<0.05) than in the other consecutive observation.

Table 1: Number of queen cells prepared per hive at the time of the active season

Observation	Year 1	Year 2	Year 3	Mean+SEM
1	7.25	15.15	14.40	12.27±9.36[a]
2	4.35	12.15	11.5	9.33±9.30[a]
3	2.75	2.75	2.00	2.50±0.41[b]
4	2.70	2.00	1.95	2.22±0.40[b]
5	1.00	0.85	0.75	0.87±0.11[b]
6	0.80	0.75	0.30	0.62±0.27[b]
7	1.40	0.50	0.00	0.63±0.70[b]
8	2.75	0.8	0.75	1.43±1.14[b]
9	2.15	0.3	0.2	0.88±1.11[b]
Mean	2.79± 2.01	2.92± 5.03	3.54±4.03	3.42± 4.50
P-value				< .0001

SEM= standard error of the mean

Foraging Behavior

In the study area, at the time of the dearth season, the honey bee race starts early (6:00) and later foraging (7:00) than the active season of the year (Table 2). In both seasons honey bee races of the worker bees in foraging activity start early and end in the late evening. The average number of bees during the last five minutes of late foraging time shows a higher number of bees out of the hive in dearth time than during the active season (29.70).

Table 2: Foraging behavior of *A.m.scutellata*

	Active season			Dearth season		
Hive no	CEFT(am)	5 LFT	FLFT (pm)	CEFT(am)	5 LFT	FLFT (pm)
1	06:15	7	06:30	5:59	11	6:35
2	06:20	12	06:29	5:59	11	6:56
3	05:40	12	06:30	6:01	64	7:10
4	06:10	8	06:29	6:03	56	7:10
5	06:10	11	06:32	6:05	4	7:06
6	06:05	9	06:30	6:00	36	7:12
7	06:10	7	06:30	5:59	30	7:10
8	06:35	32	06:25	5:56	15	6:58
9	06:10	11	06:20	5:59	40	6:58
Average	**06:10**	**12.11**	**06:29**	**6:00**	**29.70**	**7.01**

CEFT= Commencement of Early Foraging, 5LFT= last five minutes exiting number of bees at late foraging time, LFT= Finishing Time of Late Foraging

Defensive Behavior

The defensive behavior of *A. m. scutellata* at the time of the active and dearth season was observed five times in 10 minutes intervals per hive (Table 3). The result shows that the honey bee race in the area is highly aggressive during the active season and to be aggressive on average takes a time of 25.41 seconds after disturbances and follows up to the 212.20-meter distance. But during the dearth season, the colony took a long time for aggressiveness after disturbance (31.28 seconds) and followed the observer a short distance (45.58 meters).

Table 3: Indicators of defensive behavior of *A. m. scutellata*

		Active season					Dearth season				
N	Statistics	1^{st}SB (sec)	TA (sec)	NSG	NSLB	FD (m)	1^{st}SB (sec)	TA (sec)	NSG	NSLB	FD (m)
1	Mean	36.2	48.71	6.43	2.57	198.00	60.40	114.60	3.80	2.80	11.4
	SD	12.4	6.89	8.69	3.55	82.03	30.94	75.62	1.78	1.30	4.39
	Min	15.0	41.00	0.00	0.00	150.00	20.00	43.00	2.00	2.00	5.00
	Max	57.0	59.00	22.00	9.00	380.00	98.00	197.00	6.00	5.00	16.0
2	Mean	22.1	30.71	24.29	6.57	262.71	40.60	63.00	6.20	5.00	38.8
	SD	13.5	13.20	27.10	7.63	99.677	30.49	40.88	2.77	3.67	35.9
	Min	8.00	3.00	3.00	0.00	100.00	8.00	27.00	3.00	0.00	15.0
	Max	46.0	45.00	66.00	21.00	400.00	84.00	113.0	10.0	9.00	100
3	Mean	16.8	22.67	79.67	4.17	276.50	26.40	41.60	8.00	7.20	48.8
	SD	10.8	11.79	96.46	6.40	86.83	25.49	32.96	5.00	4.43	37.4
	Min	5.00	12.00	3.00	0.00	182.00	5.00	11.00	3.00	3.00	18.0
	Max	33.0	42.00	243	16.00	400.00	68.00	85.00	16.0	12.0	110
4	Mean	8.33	17.00	96.67	8.50	325.67	19.00	28.00	11.2	10.6	57.2
	SD	9.58	14.21	116.3	10.71	65.28	20.50	27.08	9.47	7.46	33.4
	Min	2.00	3.00	0.00	0.00	242.00	3.00	2.00	0.00	2.00	25.0
	Max	27.0	40.00	281.00	29.00	400.00	54.00	61.00	25.0	20.0	111
5	Mean	Over aggressive difficult to collect data					10.00	12.80	15.7	16.6	71.7
	SD						12.38	14.75	11.4	11.1	33.9
	Min						0.00	0.00	2.00	6.00	43.6
	Max						31.00	36.00	30.0	29.0	125

1^{st}SB= 1st sting time of the ball, TA = Time of aggressiveness, NSG = No sting on gloves, NSLB = No sting on the leather ball, FD = Followed distance (m), SD = standard deviation, se = second, m = meter, No = number of observation

Hygienic Behavior

The hygienic behavior of *A. m*. scutellata in apiaries revealed that the removal of the pin-killed larvae and pupae in consecutive piercing showed an improvement in the active season but at the time of the dearth season removal percentage reduced at the third round as compared to the first (Table 4). Generally, the result indicates in both seasons the race performed better hygiene. Each colony removes greater than 95% of the dead brood in three consecutive observations and the colonies indicate being highly hygienic. Especially in the first and second 24 hrs, the honey bee removed the pin-killed larvae and pupae and store some nectar and pollen in the comb cell (Fig. 1&3).

Table 4: Hygienic behavior of *A.m.scutellata*

Observation			Hive 1	2	3	4	5	6	7	Av.
Active season	1	KLP	95	100	220	100	78	100	100	108.1
		LPR	89	97	220	84	78	96	90	100.3
		R %	93.7	97	100	84	100	96	90	92.8
	2	KLP	74	98	151	100	100	100	100	98.3
		LPR	72	98	151	100	100	98	82	94.8
		R %	97.3	100	100	100	100	98	82	96.1
	3	KLP	88	83	81	100	100	100	100	93.0
		LPR	83	79	81	100	100	100	90	90.4
		R %	94.3	95.2	100	100	100	100	90	97.1
	Av.		95.1	97.4	100.0	94.7	100.0	98.0	87.3	95.3
Dearth season	1	KLP	100	100	100	100	100	100	100	100.0
		LPR	100	100	100	100	100	100	100	100.0
		R %	100	100	100	100	100	100	100	100.0
	2	KLP	100	100	100	100	100	100	100	100.0
		LPR	100	99	96	98	100	100	100	99.0
		R %	100	99	96	98	100	100	100	99.0
	3	KLP	100	100	100	100	100	100	100	100.0
		LPR	97	100	99	93	100	91	100	98.4
		R %	97	100	99	93	100	100	100	98.4
	Av.		99.0	99.7	98.3	97.0	100.0	100.0	100.0	99.1

KLP= killed Larvae and Pupae, LPR= Larvae and Pupae Removed, R= Percent removal of dead Larvae and pupae within 24 hrs, Av. = Average

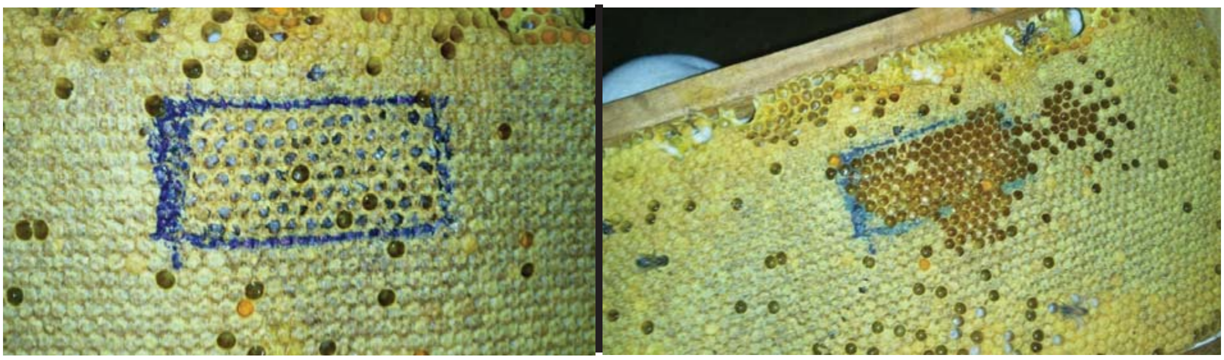
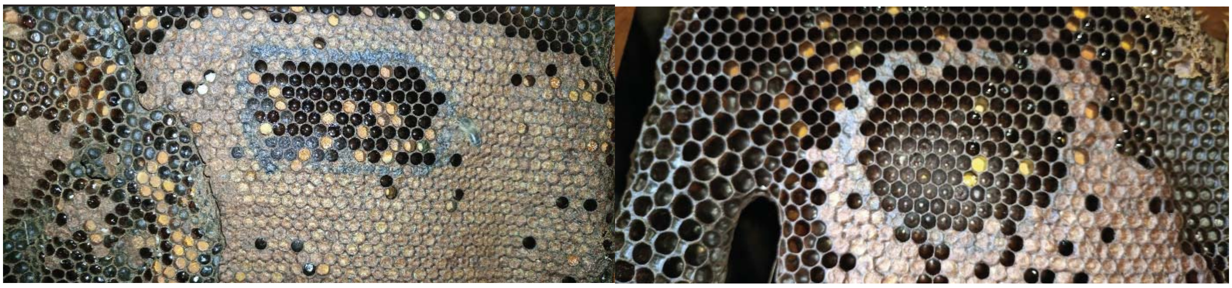


Fig 1: Active season pin-killed larvae and pupae (left) and after 24 hours (right)

Fig 2: Pin-killed larvae and pupae during the dearth season



3: First 24 hours the honey bee colonies removed the pin-killed larvae and pupae and immediately stored some pollen and nectar.

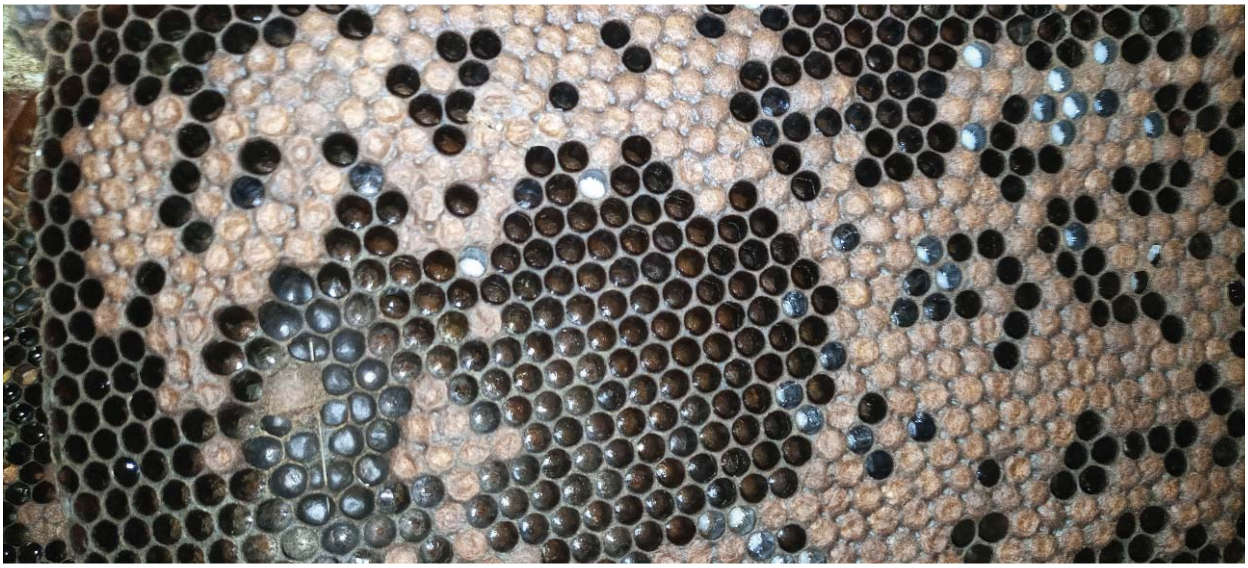


Fig 4: The third 24 hrs. repeated observation shows only removed the killed larvae and pupae and no store of pollen and nectar.

Brood, Pollen, and Nectar Collection

The brood, pollen, and nectar production data recorded in the active and dearth seasons of the year are presented in Table 5. The results indicated that the highest brood production was observed in the active season, but lower brood per hive in July and August. In the area, the brood-rearing pattern of *A. m. scutellata* honeybee colonies showed a fast buildup of the population on the 2nd 21days (October) (Fig 5). During the dearth time, the comb has higher empty cells, and as compared to the active season the colony store higher nectar in comb cells (Fig. 6).

Table 5: Brood, pollen, and nectar collection during active and dearth seasons (5x5 cm^2 units per hive from the total area)

Season		Observation	OBUH	CBUH	NUPH	PUPH
Active	1st 21 days	Hive 1	78	164	20	23
		Hive 2	78	174	14	20
		Hive 3	148	124	11	5
		Mean	101	154	15	16
	2nd 21 days	Hive 1	81	180	0	10
		Hive 2	50	198	10	10
		Hive 3	140	120	5	20
		Mean	90	166	5	13
	3rd 21 days	Hive 1	96	145	4	16
		Hive 2	15	121	0	0
		Hive 3	51	116	100	0
		Mean	54	127	35	5
Dearth	1st 21 days	Hive 1	40	80	30	50
		Hive 2	50	50	40	15
		Hive 3	15	130	15	5
		Mean	35	87	28	23
	2nd 21 days	Hive 1	10	140	10	40
		Hive 2	50	110	70	20
		Hive 3	45	81	85	26
		Mean	35	110	55	29

OBUH = Open broods unit hive, CBUH = Closed broods unit per hive, NUPH = Nectar unit per hive, PUPH = Pollen unit per hive

Fig 5: Brood, pollen, and nectar production during the active season

Fig 6: Brood, pollen, and nectar production in the dearth season

Honey Yield

Based on the production levels the peak honey flow seasons of the areas occur during November and considered as major honey flow season and April as minor harvesting season for the study area. The two year data indicates the higher honey yield was recorded during the major honey harvesting season, of the year from October to November. This might be due to the abundant availability of forage sources (*Bidens pilosa, Bidens prestinaria, and Guizotia abyssinica*) that could profoundly impact honeybee colony strength and productivity. Hence, the honey yield per frame ranged from 1.3 kg to 1.5 kg, yielding an average of 14 kg per hive per harvest.

Table 6. The honey yield (kg) of *A. m. scutellata*

Year	Harvesting season	YPFPH	TYPHPH	TYPY
1	Minor honey harvesting	1.30	13.00	28.00
	Major honey harvesting	1.50	15.00	
	Mean	0.90	14.80	
2	Minor honey harvesting	1.00	10.00	38.00
	Major honey harvesting	2.80	28.00	
	Mean	1.75	19.00	
Years	Minor honey harvesting	1.15	11.50	33.00
	Major honey harvesting	2.15	21.50	
	Mean	1.65	16.50	

YPFPH= Yield per frame per harvest, TYPHPH = Total yield per hive per harvest, TYPY = Total yield per year

Absconding Behavior

In the study area, the *A. m. scutellata* exhibited a higher absconding tendency due to pests including Wax moths and Ants, and feed deterioration (Fig. 7&8). The data showed that in a bit of disturbance 30% of the colonies in the apiary absconded at the time of the experiment. In general, in the study area, various disturbing factors (Figs. 7 & 8) influence the colony to abscond in the range of 25-47% (Table 7).

Table 7: Absconding behavior of *A. m. scutellata*

No	Colony disturbance	Disturbed colony	Absconded colony	Absconding %
1	Colony transfer	14	5	35.7
2	Hygienic data collection	10	3	30
3	Swarming data collection	4	1	25
5	Disease, pest, and feed deterioration	19	9	47.3

Fig 7: Honey bee colonies highly affected by Wax Moth (left) and Ant (right)

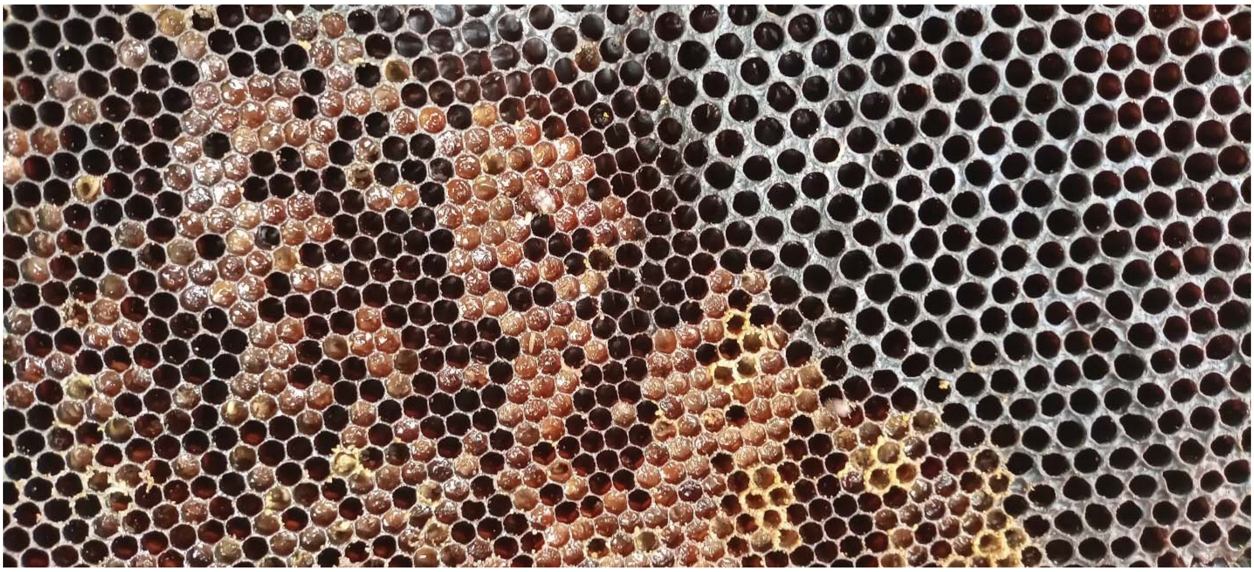


Fig 8: Affected by unidentified brood diseas**e**

DISCUSSION

The peak reproductive swarming period of *A.m.scutellata* was from October to mid-November, which could be attributed to these months being offset by heavy rains and peak plant flowering, resulting in ample bee forages (Nuru et al. 2002). While in the study area, these months are the active season for honeybees. In October, the race generated a higher number of queen caps per hive, indicating that the race had a strong swarming tendency, as evidenced by repetitive queen cell development and advanced indicators of swarming preparation. Early study shows that as compared to *A.m.bandasii, A.m.monticola, and A.m.woygambella* honey bee race of Ethiopia the *A.m.scutellata* swarmed higher per colony 10 (3 -16) (Nuru et al. 2002). These results also coincide with the previous reports that declared tropical honeybees generally have a strong reproductive swarming impulse and a tendency to increase population very quickly, leading to rapid multiplication of colonies (Schneider and McNally 1994). A study based on months indicates that 60% of *A. m. scutellata* colonies' peak swarming period is in November-December (Uzunov et al. 1992). The number of queen cells counted in this study was slightly higher than the value (2 and 2.44 queen cells per hive throughout the year) reported by Alemu et al. (2014) for *A. m. scutellata* in the Guji highland of Oromia and honey bee colonies of different genetic origin in a pan-European (Uzunov et al. 1992). Likewise, the result was in contrast with the finding of Camazine et al. (1988) who reported that Africanized honey bees swarm at a rate of six to twelve swarms per year. The variation among these reports might be due to the agroecological difference in the study areas (Nuru et al. 2002). The expression of these behavioral traits can be strongly influenced by environmental factors and beekeeping management techniques (Büchler et al. 2013).

Collecting pollen, nectar, water, and resin is critical for honey bee colonies' foraging activity (Abou-Shaara 2014). The difference in the active and dearth season in foraging activity may be related to the distance of honey bee forages, colony strength, food resources, month, and the time of the day. In both seasons the honey bee was found in our study area early forager than in studies by Joshi and Joshi (2010), who discovered that honey bee workers began foraging activity at 6.17 a.m., agreeing with the period recorded for early foraging. And also *A. m. scutellata* shows a longer cessation time than *A. m. Woyi gembela.* According to Duangphakdee et al. (2011) *A. m. Woyi gembela* return to their nest after completing foraging activities before the sun sets at 6:27 pm. In contrast to the findings of this study by Solomon and Likawent (2015), the foraging behavior of honey bee races (*A. m. monticola*) assigned to various agroecologies demonstrated high competence to natural resources by foraging early (as early as 5:25 am) and returning late (as late as 7:04 pm). Sharif et al. (2020) have suggested in a review paper the use of novel honeybee colony monitoring systems that can assist beekeepers to know about the foraging of their bees at a spatial scale. This may help beekeepers to detect directions as well as the distance where rich food sources are present. With this information, beekeepers can decide where to relocate their apiaries in the coming days.

It is advantageous to know the season at which the bees are more aggressive and those when they are less aggressive (Woyke 1992). The result indicates that the *A. m. scutellata* race was aggressive, implying that the race was able to develop strong colonies throughout the active season, resulting in good hygienic behavior and quality honey production. The highly aggressive behavior of the race is also advantageous to provide a good defense against honeybee pests. Indeed, the aggressiveness of the race might be attributed to improved apiary management, bee forage improvement, and the carrying capacity was optimized in a study area rather than the genetic trait of the race. Consecutive observations revealed at the time of active season the race was very aggressive, making data collection difficult. Inspection and honey harvesting are done at night due to high defensive behavior. In addition, beekeepers in the region must choose an apiary site that is far away from their homes, farms, and grazing land to protect animals and humans from honey bee stings. At the time of data collection (from September to December) with smoke, the colony shows a strong defensive reaction to being handled, or bees attack without being disturbed and bees nervously leave the combs, run out of the supers, and cluster inside or outside the hive. This finding supports early studies that *A. m. scutellata* honeybees are very defensive (Ruttner 1988). Another study also found that *A. m. scutellata* is more aggressive from September through November (Crane 1990). Moreover, the present study shows in both seasons the average following distance is in line with the study by Regina et al. (2014) which shows the average observer's following distance ranged from 23.33 ± 5.85 meters to 216.6 ± 7.95 meters, and when the colony shows following distance 123-meter distance higher in defensive behavior.

In both active and dearth seasons *A. m. scutellata* race hygiene was good (>95%), compared to an unhygienic situation (<90%), which can lead to better honey production and prevent disease caused by unhygienic conditions. Concurrent with the result of this study Sheppard et al. (1997) reported that honeybee colonies that removed over 90% of dead broods within 24 hours are considered hygienic. Alike to the result of this study Abdullah et al. (2007) reported that the honey bee race recognizes and removes diseased, damaged, or dead brood and indicates higher hygienic behavior which also is a mechanism of colony resistance to American foulbrood if bees can remove brood from the nest before the pathogen becomes infectious. The active season result of this study was in line with the finding of Boecking and Spivak (1999), who reported that *A. m. scutellata* successively (94% - 99%) removed the pin-killed capped brood removal in 24 hours from November to February in the highland area of the Guji Oromia region.

The highest brood rearing was recorded in the active season, which could be because the region is rich in many types of honeybee flora, ranging from weeds to forest trees, which provide ample bee forage in this month. Studies show *Apis mellifera* bees in tropical, rear brood throughout the year, but reduce the amount of brood reared during the rainy season (Winston 1987). In general lack of studies on such races in east Africa on population dynamics in both bees and brood production affects the development of appropriate beekeeping management strategies using the modern moveable frame.

The higher honey yield was recorded during the primary honey harvesting season of the year from October to November and this might be due to the abundant availability of forage sources that could profoundly impact honeybee colony strength and productivity. This honey yield recorded for this race was higher than the race found in the highland area in mean honey yield (kg) per harvest per hive (9.64+3.02, 11.54+1.87) (Boecking and Spivak 1999). This difference may be because of the fact that honey yield is influenced by several factors and is significantly associated with colony conditions (Crane 1990).

The race shows a higher absconding rate from mid-December to mid-February and in the rainy season from July to mid-September due to feeding deteriorations in these periods. According to evidence gathered from personal conversations among beekeepers, the race-high absconding tendency, particularly after colony transferring, honey harvesting, and feed deterioration period, is the region's most serious beekeeping issue. The study by Crane (1990) also shows that migration and absconding are also highly characteristic of African honeybees. They leave their nests during dearth periods and unfavorable conditions and move to a more suitable locality. Moreover, in the study area, honey bee colony absconding may be related to the honey harvesting system and colony movement with seasonally shifting due to honey bee forage availability in the forest area (locally known as Berha).

Conclusion

Overall, our results demonstrate *A. m. scutellata* honeybee colonies show a higher defensive and absconding tendency. However, the race has good performance in foraging and hygienic behaviors. The honeybees have a high tendency for swarming. A higher queen cap prepared leads to repeat swarms from a single colony. Future research should consider the potential effects and management practices to reduce a higher absconding rate of the colony. In addition, further studies could be conducted on the selection and breeding of the best-performing colony of *A. m. scutellata* to reduce aggressiveness (higher defensive behavior). Further, researchers should also explore the foraging efficiency of A. m. scutellata bee-race in terms of trip duration that is, how long foragers spend traveling to a food source during active and dearth periods.

Funding: This project is funded by the Ethiopian Institute of Agriculture Research and the authors acknowledged the financial support.

Ethical statement: The ethical statement does not apply to this study and does not involve any animal that requires approval from the ethical committee

Statements and Declarations: The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contribution Statement: The authors confirm their contribution to the paper as follows: Author AT. Draft manuscript, study conception, data collection, design, data analysis, data interpretation, full writeup, Author MF. Draft manuscript, data collection, data analysis, interpretation of result and writeup of the manuscript and, Author AA. Data collection, supervision, and data analysis. All authors reviewed the results and approved the final version of the manuscript.

Acknowledgment

We would like to thank the Ethiopian Institute of Agricultural Research and Assosa agricultural research center which supported this experiment. Special thanks to the Assosa Agricultural Research center livestock researcher and field assistant for their technical cooperation while accomplishing this experiment. Finally, thanks to the Oromia Agricultural Research Institute (IQQO) Holeta Bee Research Center for their technical follow-up and support starting from the proposal preparation up to the completion of the experiment.

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