MELLIFERA RESEARCH ARTICLE

Seasonal Variation in Forage Plant Selection, Foraging Time, Duration and Preference of *Apis mellifera adansonii* in the Rainforest and Semi-savannah Ecosystems of Nigeria

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ABSTRACT

The foraging behaviour such as plant selection, time, duration and floral preference of colonies of *Apis mellifera adansonii* were studied during the dry and wet seasons in 2012 -2014. Colony observations were made from 6:00 am - 7:30 am, 11:00 am - 1:00 pm and 6:00 pm - 7:30 pm during the period, meteorological data on sunset and sunrise, moonrise and moonset were collected for the time of observations of the foraging workers. All the time recorded for the start and end of foraging were local time for the study sites. The floral plant species distributed in 3 kilometer radius of the colony sites were sampled. Honey and pollen combs were also collected from all the experimental colonies for mellisopalynological investigations. There was a difference between the abundance of foraging plants in the savannah and rainforest zones in the tropics as indicated by Jacard's (Cj) and Sorenson's (CS) similarity coefficient of 0.37 and 45.9% respectively. The bees average starting and ending times of foraging were 07:01 h and 18.20 h respectively and the average duration of foraging was 11:30 h per day. During the dry and wet seasons, the foraging time and duration was not significantly different ($P < 0.05$). Pollen analyses showed that the bees in the savannah ecosystem visited more flowers than those in the forest ecosystem; the former had a significantly higher pollen sum of 254 and 543 during dry and wet seasons respectively ($P < 0.05$). The colonies in both forest and savannah areas showed preference for Elaeis *guineensis* Jacq.(Arecaceae). Results from this study have given insights into the "bee plants" of the two ecosystems as well as providing information to bee keepers about the behaviour of bees for improved apiary management.

Keywords: Foraging, floral preference, pollen, nectar, *Apis mellifera adansonii*

Introduction

Apis mellifera adansonii Latreille, 1804 compared to the European honey bee (Apis mellifera mellifera L.) have high foraging power but low productivity because it consumes more of the honey hoards in the period of nectar and pollen dearth [1]. The basic foods of honey bee colony are nectar and pollen [2,3,4]. Worker bees during foraging, gather and collect pollen and nectar from flowers of plants. The pollens are used by the bees to make pollen bread and nectar is used for honey. The nectars are the derivatives of phloem sap which are formed from specialized group of cells

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called nectaries [5]. The nectaries are termed floral part, if they occur as part of a flower or extrafloral, if they occur elsewhere on a plant [6,7,8]. Nectary contains nectar which is an aqueous solution of sugars [9]. Similarly, pollen grains are usually present in floral part called anther suspended by a structure called filament, both collectively referred to as stamen [10].

During foraging, *A. mellifera adansonii* visit diverse and selective plant species for nectar and pollen. These foraging workers have two types: the scout bees and reticent bees. The latter constitute 40–90% of the total foragers' population [11]. Foraging activity is initiated by the scout bees that go to the field, return and display a dance communication and odour plume to alert the reticent bees about the food source, location and distance [12]. The foragers select their foraging plants for nectar, pollen and resin; they collect water, and can also collect wax from scale insects, *Ceroplastes* sp. [13].

The foraging activity starts in tandem with the sunrise and sunset. However, this activity is greatly affected by the regional and climatic conditions. For example, Joshi and Joshi [14] and Alqarni [15] claimed under a desert condition, a higher number of foragers left the colonies at 10 am. The foraging activities whether for pollen or nectar is impacted by many factors. These factors can be divided into two major groups: in-colony factors and out-colony factors [16]. The in-colony factors include genetic factors -: colony-level trait [17], and the genotype of bee strain (e.g. high and low pollen-hoarding bees) strongly affected foraging behaviour for nectar or for pollen [18], the pollen demand of the colonies [4], the specific position of one flower over another [19]; colony strength and brood rearing activity [20,21], mated or virgin queen [22]; types of bee hive; and the hygienic status of foraging bees which may halt their return to their colonies or increased time to return when on forage [23]. The out-colony factors include: availability of suitable plant resources and other environmental factors such as temperature, humidity and time of the year [16,24].

Foraging worker bees may change from water foragers to pollen foragers in relation to the colony conditions. In this case, foragers use their experience in trophallactic contacts to assess the pollen need of their colonies [4]. Similarly, where there are shortages of pollen or in conditions of pollen dearth, honey bee colonies may increase the proportion of pollen foragers without increasing foraging rate [25].

Honey bees show floral constancy during foraging. There are many examples of foraging preference; nectar and pollen preference were observed due to the specific position of one flower over another [19]. According to Fohouo et al. [26], highest number of foraging workers were attracted to *Syzygium guineense* var. *guineense* (Myrtaceae) and the lowest number on *Psorospermum febrifugum* (Hypericaceae) because of abundance and availability of the target vegetation.

The pollen content of the honey not only reflects agricultural practices and surrounding vegetation but also the floral diversity and species composition of the melliferous plant species nearby the apiary [27]. Abou-Shaara [16] suggested and cited some standard methods for monitoring the foraging activity of the honey bees :- caging in net conditions[19]; marking and recapturing foraging workers [1]; self-marking devices for studying the foraging range [28]; video recording in insect-proof tunnels [29]; pollen traps [30] and

harmonic radar to record flight paths of foraging honey bee workers [31,32]. Foraging activity can be measured by employing different parameters including, the commencement or/and cessation time [14].

Therefore, to improve on current knowledge of our understanding of honeybee floral preference and foraging behaviour, colonies of *Apis mellifera adansonii* in apiaries located in the rainforest and semi-savanna ecosystems of Nigeria were studied during the wet and dry seasons. The objectives were to compare the relative abundance of foraging plants, foraging time, duration and floral preference of the freely foraging colonies of *Apis mellifera adansonii*. Results from this study will give insight into the activities of this bee species and therefore improve hive management for greater profits for beekeepers.

Material and Methods

Study sites

Field investigations were carried out in two large apiaries located in Oyan, Odo-Otin and Ife South Local Government Areas, in Osun State, Nigeria. The farm locations are in the geographical coordinates of 8°2'0"N, 4°42'0"E and 7°31'3"N and 4° 31'34"E respectively, Odo-Otin belongs to a semi-savannah and Ife South belongs to a rainforest ecological zone (Figure 1). Foraging activities

Observations of foraging time were done by using a Time Lapse Video Camera (TLC200 pro HDR) during the dry and wet seasons of 2012-2014, in eight randomly selected free-foraging colonies, four from each farm sites for fifteen days in

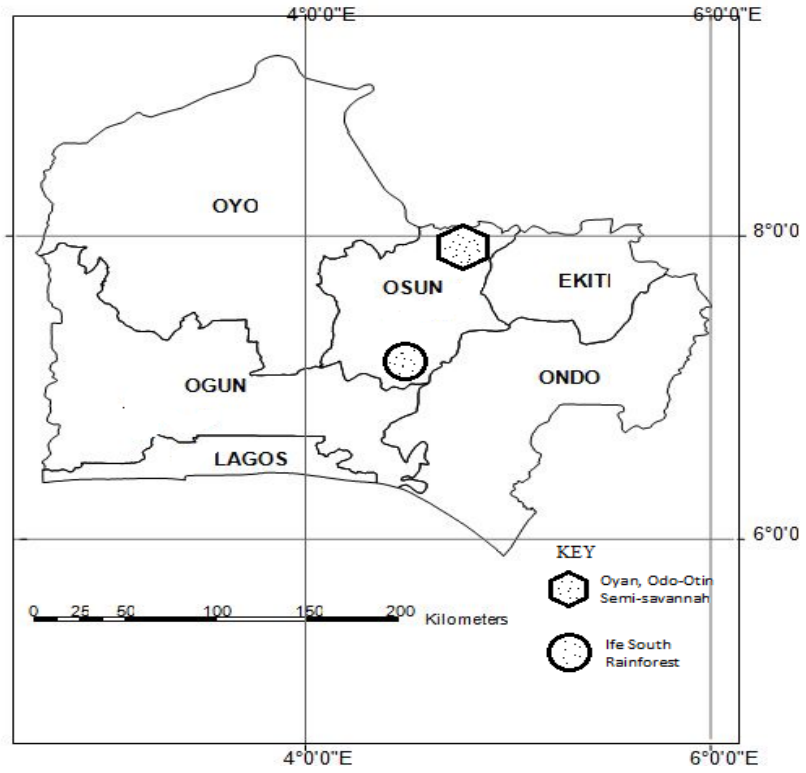

Figure 1. Map showing the locations of the two apiaries, Oyan,Odo-Otin and Ife South LGAs

December (dry season) and fifteen days in June (wet season). The camera was set to record activities in the time lapse of 5:40-7:20 am, 11:00 am-1:00 pm and 5:40-7:20 pm and information downloaded thereafter. We collected the meteorological data on sunset and sunrise, moonrise and moonset during each time we observed the workers' foraging time and duration. The foraging time was taken as the time a bee/bees took the first outbound flight from the hives and ending time was taken when all the bees that have left the hive returned to assemble for the night. All the time recorded for the start and end of foraging were local time for the study sites. Colony foraging duration was the length of time recorded from start to end of foraging, while the day length was calculated from meteorological data obtained.

Palynological analysis

Plant, Honey and Pollen combs sampling

Honey combs and pollen combs were sampled from each of the eight selected colonies. The surrounding vegetation within 3 kilometers radius of each apiary were sampled. Afterwards all the plant samples were pressed and brought to the University of Lagos Herbarium for identification. The identification of the plant specimens were accomplished to the family, genus and where possible to species levels. Those that could not be identified were regarded as unidentified.

Isolation of pollen grains from honey and pollen combs

Microscopic pollen analyses of each honey and pollen comb samples were done by using the methods given by the International Commission for Bee-Botany [33,27] and Laboratory work included acetolysis treatment of samples according to Erdtman [34] and Shubharani [35], microscopic analysis of prepared residues and preparation of reference pollen slides from plant specimens collected during sampling in the field. Two fields of view each were microscopically studied per sample.

Identification of recovered pollen grains was done with the aid of pollen atlases, and other published floral catalogues and journals such as Sowunmi [36]; Agwu and Akanbi [37]. Photomicrographs of some important pollen grains were taken with a Motic 2000 digital camera. (See Plate 1)

Statistical Analysis

Data collected from mellissopalynological analyses were analysed using descriptive statistical measures of frequency, classification of frequencies according to Louveaux et al. [27] and relative abundance. Inferential statistical techniques of sample t-test were used to evaluate significant differences between different relative abundance of pollen, foraging time and duration. Bee foraging plant species were identified and Jaccard (Cj) and Sorenson (Cs) Similarity Coefficients were used to compare the abundance of the foraging plant species in semi-savannah and rainforest ecological zones.

Results

We observed many varieties of honey bee foraging plants in both the semi-savannah and rainforest ecological zones in the tropics. In the rainforest, during the dry and wet seasons, the honey bees *Apis mellifera adansonii* were found to forage on 15 plant and 17 plant families respectively having a total of 28 plant species (Table 2). Jacard's (Cj) and Sorenson's (CS) similarity coefficient of 0.52 and 50% were obtained respectively, showing similarity between the abundances of the foraging plants during the wet and dry seasons (Tables 2

and 3). On the other hand 22 and 18 plant families having a total of 46 plant species (Table 1) were analysed as foraging plants in the semi-savannah ecological zone during the dry and wet seasons; Jacard's (Cj) and Sorenson's (CS) similarity coefficient of 0.46 and 51.2% were obtained respectively, showing similarity between the abundances of the foraging plants during the wet and dry seasons (Table 2). According to these analyses there is no similarity (Jacard's (Cj) and Sorenson's (CS) similarity coefficient of 0.37 and 45.9% respectively) between the abundances of foraging plants in the semi-savannah and rainforest zones in the tropics (Table 2).

The bees showed varying degree of preference for pollen types of different foraging plants. In both the rainforest and semi-savannah ecological zones, foraging worker bees showed low constancy for pollen from *Elaeis guineensis* Jacq. (Araceceae) and occasional frequency for pollen from *Alchornea cordifolia* Schum & Thonn

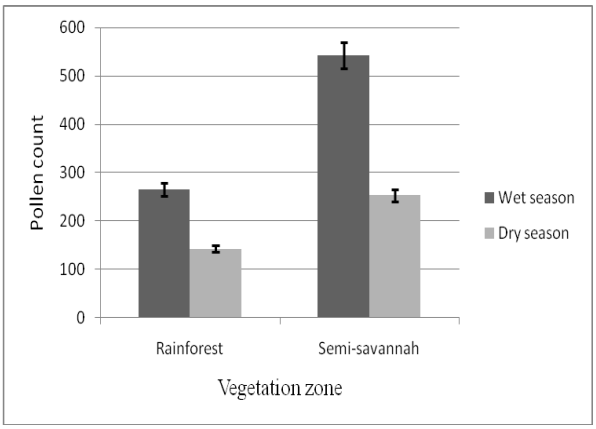

Figure 2. Comparison of pollen count in the honey and pollen comb samples in the semi-savannah and rainforest vegetation

(Euphorbiaceae). In the savannah, the bees show occasional frequency for pollen from *Sporobolus pyramidalis* P.Beauv. (Poaceae). In the rainforest, the bees occasionally frequent more pollens from *Syzygium guinensis* Willd Conocarpus eracta Linn. (Combretaceae), *Anacardium occidentale* Linn.(Anacardiaceae), *Amaranthus viridis* Linn. (Amaranthaceae), *Gomphreria celosioides* Mart (Amaranthaceae), *Albizia glaberrina* Schumach. & Thonn (Mimosoideae), *Manihot esculenta* Crantz, *Securinega virosa* Roxb. ex Willd and *Euphorbia hirta* Linn (Euphorbiaceae) (Table 1, Figure 3a, b and c). In the rainforest zone with a diverse and rich vegetation, the total pollen recovered during the wet season was 266, and during the dry season it decreased to 143 (Figure 2). Similarly, in the semi-savannah ecosystem, the pollen foraged during the wet season was 543 and during the dry season it decreased to 253 (Table 1 and Figure 2). The extensive human interference of this derived savannah had impacted its biodiversity, the rainforest, though equally impacted but was able to provide more diversed flora for the bees use. The reported importance of *Elaeis guinensis* in honey production by several workers in Nigeria is also exhibited in this study. This is reflected by the pollen of *Elaeis guinensis* (Table 1) with a record of 257 counts out of a total recovered pollen of 543 in the honey and pollen comb samples in the semi-savannah area. Its relative abundance of 47.33 % during the wet season assigns "very frequent" classification according to Louveaux et al. [27]. In the rainforest, *Elaeis guinensis* pollen recorded 96 out of a total of 266 recovered pollen from the honey and pollen comb samples. This pollen type also showed a "frequent" classification with its relative abundance of 36.09 % (Table 1) during same wet season. Apart from *E. guineensis*, another important pollen types recorded in this study were *Syzygium guineense* with a "frequent" classification in the rainforest and Euphorbiaceae pollen type with also "frequent" classification in the semi-savannah. Other pollen

Table 1. Pollen count, relative abundance and frequency class from honey comb samples during the wet season from rainforest and semi-savannah

Vegetation	Rainforest			Savannah		
Plant family	Pollen count	Relative abundance	Frequency class	Pollen count	Relative abundance	Frequency class
Asteraceae	10	3.76	Rare	26	4.78	Rare
Malvaceae	22	8.27	Occasional	7	1.28	Rare
Myrtaceae	55	20.68	Occasional	3	0.54	Rare
Sapotaceae	5	1.90	Rare	-	-	-
Mimosaceae	1	0.38	Rare	-	-	-
Euphorbiaceae	22	8.28	Occasional	113	20.81	Occasional
Poaceae	11	4.14	Rare	56	10.31	Occasional
Solanaceae	7	2.63	Rare	3	0.54	Rare
Amaranthaceae	2	0.76	Rare	8	1.47	Rare
Arecaceae	96	36.09	Low constancy	257	47.33	Low constancy
Fabaceae	1	0.38	Rare	-	-	-
Cyperaceae	1	0.38	Rare	-	-	-
Rutaceae	4	1.50	Rare	-	-	-
Meliaceae	1	0.38	Rare	-	-	-
Onagraceae	3	1.12	Rare	-	-	-
Rubiaceae	-	-	-	11	2.02	Rare
Myricaceae	-	-	-	1	0.18	Rare
Schrophulariaceae		-	-	1	0.18	Rare
Bignoneaceae	-	-	-	1	0.18	Rare
Sapindaceae	-	-	-	2	0.36	Rare
Portulaceae	-	-	-	1	0.18	Rare
Rubiaceae	-	-	-	11	2.02	Rare
Combretaceae	22	8.27	Occasional	3	0.55	Rare
Anacardiaceae	3	1.12	Rare	5	0.92	Rare
Steculiaceae	-	-	-	34	6.26	Occasional
POLLEN SUM	266	100		543	100	

(*Plant families identification using floral catalogues and journals* [36, 37]. *Frequency class is according to Louveaux et al. [27], Relative abundance (%)*

types in both the dry and wet seasons' recoveries recorded "rare" classification.

The pollen count and abundance from the samples in the wet and dry seasons in the rainforest ecosystem significantly reduced ($t = 3.630$, $df = 29$, $p = 0.001$) (Table 3, Figure 2). Likewise, in the semi-savannah ecosystems, the pollen count and abundance from wet to dry seasons reduced significantly ($t = 2.877$, $df = 27$, $p = 0.008$ ($p < 0.050$) (Table 3, Figure 2). The pollen counts in the honeys and pollen combs of the bee colonies

Table 2. Jaccard and Sorenson Similarity Coefficient of relative abundances of bee forage plant species

	Forest	**Savannah**	
Similarity coefficient	Dry/Wet	Dry/Wet	Savannah/Forest
Jaccard's similarity coefficient (C_j)	0.52	0.46	0.37
Sorenson's similarity coefficient (C_s)	50.0%	51.6%	45.9%
Result	Similar	Similar	Dissimilar

from the forest and the savannah were significantly different (t = 4.603, df = 57, P < 0.001 (Table 3).

The colonies were found to commence foraging early morning 07:02 ± 0:03AM and ended in the evening between 18:20 ± 0:00 to 18:56 ± 0:00PM. The individual bees were not observed for foraging time. The mean duration of foraging in the wet and dry season in the forest and savannah were not significantly different (p < 0.001). Though, the mean duration of day length was longer in the wet than dry seasons (Table 4).

vation was reported also by many authors in their works. Ayodele *et al* [38] recorded 49 melliferous plant species in the forest and 5 out of the 49 species were dominant in the derived savannah zones of southwestern Nigeria. Mbah and Amao [39] also recorded a total of 28 plant taxa visited by honey bees *Apis mellifera adansonii* in Zaria, in the savannah belt of Nigeria and 61 plant taxa were also visited by honey bees in Sudan savannah zone in northeast Nigeria.

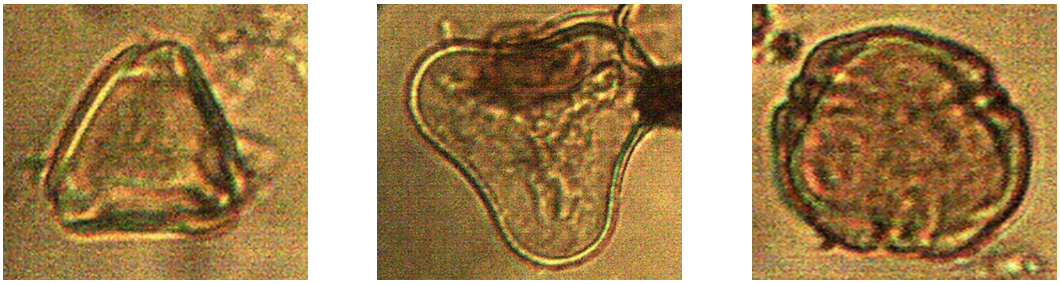

Figure 3:. Photomicrographs of pollens from

(a) *Syzygium guineense* **(b)** *Elaeis guineensis* **(c)** *Alchornea cordifolia* **(**Mag. X400)

Discussion

The wide range of pollen isolated from the honey and pollen comb samples from the two ecological zones, apparently, showed that the honey bees selected many plants for foraging among the different plants present in both the semi-savannah and rainforest ecosystems. This obser-

The very frequent and frequent classifications of *Elaeis guineensis* Jacq. (Araceceae) pollen type and rare classification of *Alchornea cordifolia* Schum & Thonn (Euphorbiaceae), Syzygium guineense Willd (Myrtaceae) and Asteraceae pollen types etc (Table 1) in the two ecological areas were at variance with the observations of

Table 3. t-test analysis of pollen counts in the honey samples from rainforest and semi-savannah.

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Savannah	2.877	27	0.008	6.60321	1.8939	11.3125
Forest	3.630	29	0.001	6.91533	3.0191	10.8116
Forest/Savanna	4.603	57	0.000	6.76466	3.8216	9.7077

many authors in the savannah area in Nigeria. Fohouo et al.[26] and Mbah and Amao [39] recorded pollen types of *Tridax procumbens* , *Tectonia grandis* and Malvaceae as the most foraged. Ayansola and Davies [40] also recorded *Aspilia Africana, Chromolaena odorata, Manihot esculenta, Talinum triangulare and Amaranthus viridis* were frequently foraged taxa in the south-western Nigeria. In the Sudan Savanna zone in North-eastern Nigeria, Dukku [41] recorded *Azadiracta indica* (Meliaceae), *Tectona grandis* (Verbenaceae) and *Tridax procumbens* (Asteraceae) pollen types as mostly foraged plants species. With these different dominant pollen recorded by all these authors, it is clear that bees search for pollen among plants that are available in each ecological area as long as the pollen are good for them as food. Again, the result of Ige and Modupe [42] in the analysis of 20 honey samples from two different localities in two states in the North Central, Nigeria, a savannah zone, showed that *Elaeis guineensis* (Araceceae) and *Poaceae* were dominant in their honey samples, this is an indication that the pollen and/or nectar of these plant species were important bee foods. Our findings on bee forage preference further agreed with Abou-Shaara [16] conception that bees are plant specific in their foraging due to some resources present in their pollens and or nectaries. Similarly, the pollen preference of the honey bee foragers reflected the climate and vegetation of the hive areas. This finding was rightly stated by Aycan et al [43] that pollen preference of honey bee foragers reflected the flora of the area and its climate. Ige and Apo [44], Adeonipekun [45], Aina and Owonibi [46] remarked that high species diversity is characteristic of vegetation in the tropics, where they recovered 36, 43, and 45 plant taxa respectively from Nigerian honeys, pollen pellets and pollen load samples and this high species diversity of the vegetation in the tropics truly influenced the foraging preference of bees. In spite of these high species diversity, bees are still specific in their foraging.

Again, our finding that seasonal changes also influence bee foraging activities supported [47,48,49] who had earlier reported this in their field work. This was further confirmed by Tirado et al [50] who studied foraging activities of social insects and reported that their activities were influenced by not only climate but also seasonal changes, timing and location of food. The earlier works on timing of foraging by bees have indicated that higher activities started early in the morning to midday and decreased in the evening. For example, Alqarni [15] observed in the desert a higher number of forag-ers leaving their colonies at 8.00 am more than at 10.00 am, Joshi and Joshi [14], observed that honey bee workers started foraging by 6.17 am in the sub-tropics while Haftom

et al [51] recorded the highest numbers of honeybees commencing foraging at 10:30 - 11:30 am, with the least number recorded at 16:30 - 17:30 pm. From our findings, average starting time was 7.00 am in the rainforest and 7.03 am in the semi-savanna and ceasation time in both the rainforest and semi-savanna was 18.38 pm. The average duration of bee foraging activity was 11.36 h in both ecosystems. This again agreed with earlier works that bees foraging started early in the day and by evening; activities are brought to a halt. Of course, most plants open their flowers in the morning to afternoon during heavy sunlight and by evening some flowers are closed. It was possible to conclude that season, length and time of the day, sunset and sunrise and region had significant effect on pollen abundance and bee foraging.

Conclusion

The rainforest and semi-savannah ecosystems have rich and diverse bee foraging plants. West African honey bee, *Apis mellifera adansonii* foraged during the wet and dry seasons, and foraged many plant species. In the savannah, the honeybees most frequently visited *Elaeis guineensis* Jacq.(Araceceae) while in the rainforest, the honeybees frequently visited *Elaeis guineensis*. Jacq (Araceceae) and *Syzygium guinensis*. Willd. (Myrtaceae). Foraging activities of *Apis mellifera adansonii* colonies either in the savannah or forest or during the dry or wet seasons; started nearly at the same time of the day. Floral preference and foraging behaviour were regulated by floral availability, abundance and season, to an extent duration and time of the day. The discovered bee preference for some plants as pollen sources has further supported their significance in honey bee farming in Nigeria and also encourages and assures migrant beekeepers of the availability of good forage when moving from the forest to the savannah part of the country.

Table 4. Summary of 15 days observation of foraging time and duration during the dry in all colonies

Season	Apiary	Mean day length HR	Av. starting time AM (15 days)	Av. ending time PM(15 days)	Mean duration of foraging	Asymp. Sig.
Wet[a]	Rain Forest	12:31± 0:00	7:00 ± 0:02	18:56 ± 0:00	11:55 ± 0:01	0.000
Dry[b]	Rain Forest	11:42 ± 0:00	7:03 ± 0:03	18:20 ± 0:00	11:17 ± 0:03	(p<0.05)
Wet	Semi - savannah	12:32 ± 0:00	7:03 ± 0:03	18:56 ± 0:00	11:53 ± 0:03	0.000
Dry	Semi - savannah	11:42 ± 0:00	7:02 ± 0:03	18:20 ± 0:00	11:17 ± 0:03	(p<0.05)

Nijerya'nın Yağmur Ormanları ve Yarı-Savan Ekosistemlerindeki *Apis mellifera adansonii*'nin Nektarlı Bitki Seçimi, Tarlacı Dönemi ile Süresi ve Tercihindeki Mevsimsel Değişim

ÖZ

Apis mellifera adansonii kolonilerinin bitki seçimi, zamanı, süresi ve çiçek tercihi gibi tarlacı davranışları 2012-2014 yılları süresince kurak ve yağışlı mevsimlerde incelenmiştir. Koloni gözlemleri dönem boyunca sabah 06: 00-7: 30, 11:00-13:00 ve 18:00-19:30 saatleri arasında yapılırken tarlacı işçi arıların gözlemleri sırasında gün batımı ile gün doğumu, ay doğumu ile ay batımı arasındaki meteorolojik veriler toplanmıştır. Tarlacı davranışlarının başlangıcı ve bitişi için kaydedilen bütün zaman tanımları için çalışmaların yapıldığı alanın yerel saati kullanılmıştır. Koloni bölgelerinin 3 km yarıçapına yayılmış olan floral bitki türleri örneklenmiştir. Mellisopalinojik araştırmalar için tüm deneysel kolonilerden bal ve polen petekleri toplanmıştır. , savan ve tropik yağmur orman bölgeleri arasında nektarlı bitkiler bolluğu açısından fark olduğu Jacard'ın (Cj) ve Sorenson'ın (CS) sırasıyla %0.37 ve %45.9 benzerlik katsayı-

sı oranı ile belirtildiği şekilde gözlenmiştir. Arıların, tarlacı davranışlarının ortalama başlangıç ve bitiş saatleri sırasıyla 07:01 ve 18:20 arasında olup ve günlük ortalama tarlacı süresi 11:30saattir. Kurak ve yağışlı mevsimlerdeki tarlacılık zamanı ve uzunluğu önemli ölçüde farklı değildir (P<0.05).Polen analizleri, savan ekosistemindeki arıların orman ekosistemdekilerine göre daha fazla çiçeği ziyaret ettiğini göstermiştir. Savan ekosistemindekilerin toplam polen sayısı, kurak mevsimde 254 iken yağışlı mevsimde 543'tür (P<0.05). Hem orman hem de savan bölgesindeki koloniler, *Elaeis guineensis* Jacq.(Arecaceae)'i tercih etmişlerdir. Bu çalışmanın sonuçları, iki ekosistemin "arı bitkileri" hakkında bilgi vermenin yanı sıra gelişmiş arıcılık için bilinmesi gerekli olan arı davranışları hakkında arıcıları da bilgilendirmektedir.

Anahtar Kelimeler: Polen toplama, çiçek tercihi, nektar, *Apis mellifera adonsonii*

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