Citation/Atıf: Sharif MZ, Xue R, Puswal SM, 2020. Foraging Performance of Honeybee (Apis mellifera) Affected By Food Richness And Experience, (Gıda Zenginliği ve Deneyiminden Etkilenen Bal Arısının (Apis mellifera) Yayılma Performansı), U.Arı.D.-U.Bee.J. 20(2): 132-144, DOI: 10.31467/uluaricilik.764307

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

FORAGING PERFORMANCE OF HONEYBEE (*APIS MELLIFERA*) AFFECTED BY FOOD RICHNESS AND EXPERIENCE

Gıda Zenginliği ve Deneyiminden Etkilenen Bal Arısının (*Apis mellifera*) Yayılma Performansı

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Geliş Tarihi / Received: 05.07.2020 Kabul Tarihi / Accepted: 29.08.2020 DOI:10.31467/uluaricilik.764307

ABSTRACT

For honeybees (*Apis mellifera*), food richness and experience have significant impacts on making foraging decisions. Bees that trace food-rich source they start establishing spatiotemporal memories, which assist them in revisit the particular site on following days. The present study explored whether different levels of food richness (10%, 30%, and 50% sugar solution, and unrewarding situation) at a feeding source affect the number of forager bees for their visitation and how the previous experiences affect bees for their foraging duration. More bees persist visiting food-rich sources. However, the diminution in food richness consequence a gradual decline in the number of bees, but they persistently visiting feeding sites for several days, even if unrewarded with food-rich sources. Regardless of comparison with the bees visiting a low sugar solution, the number of bees visiting higher sugar solution decreases with the time. The foraging efficiency of bees in terms of trip duration also increased with the experiences of previous visits. In conclusion, bees exhibit considerable attachment with experienced feeding sites that stop providing food anymore, and the duration of the foraging trip decreases with the experience (19 to 2 min one-way trip for 251 m distance). We, in our current findings, confer the implications for future investigation on the research gap concerning the altering foraging situations.

Keywords: *Apis mellifera,* Population Dynamics, Foraging Behavior, Food and Experience

ÖZ

Bal arıları (*Apis mellifera*) için, besin zenginliği ve deneyimi, yiyecek arama kararlarında önemli etkilere sahiptir. Besin açısından zengin kaynağın izini süren arılar, sonraki günlerde belirli bölgeyi yeniden ziyaret etmelerine yardımcı olan mekansal-zamansal anılar oluşturmaya başlarlar. Bu çalışma, bir besleme kaynağındaki farklı seviyelerde gıda zenginliğinin (%10, %30 ve %50 şeker çözeltisi ve ödülsüz durum) ziyaretleri için yayılmacı arı sayısını etkileyip etkilemediğini ve önceki deneyimlerin arıları yiyecek aramaları için nasıl etkilediğini araştırıldı. Daha fazla arı, besin açısından zengin kaynakları ziyaret etmeye devam etmektedir. Bununla birlikte, besin zenginliğindeki azalma, arı sayısında kademeli bir düşüşe neden olur, ancak onlar, besin açısından zengin kaynaklarla

ödüllendirilmemiş olsalar bile, birkaç gün boyunca beslenme alanlarını ısrarla ziyaret ederler. Düşük şekerli bir solüsyonu ziyaret eden arılarla karşılaştırılmasa da daha yüksek şekerli solüsyonu ziyaret eden arıların sayısı zamanla azalır. Arıların gezi süresi açısından yiyecek arama etkinliği de önceki ziyaretlerin deneyimleriyle artmıştır. Sonuç olarak, arılar artık yiyecek sağlamayı bırakan deneyimli beslenme alanları ile hatırı sayılır bir bağlanma sergilerler ve besin arama gezisinin süresi deneyimle birlikte azalır (251 m mesafe için 19 ila 2 dakika tek yön yolculuk). Mevcut bulgularımızda, değişen besin arama durumlarıyla ilgili araştırma boşluğuna ilişkin gelecekteki araştırmalar için çıkarımlar sunmaktayız.

Anahtar kelimeler: ***Apis mellifera,*** **Populasyon Dinamiği, Yayılma Davranışı, Gıda ve Deneyim**

GENIŞLETILMIŞ ÖZET:

Çalışmanın amacı: Araştırmamızın temel amacı, bir beslenme kaynağındaki farklı gıda zenginliği düzeylerinin veya ödüllerin, koşullar ödülsüz duruma geçtikten sonra bu yeri ziyaret edecek yayılmacı arıların sayısını etkileyip etkilemediğini araştırmaktı.

Gereç ve Yöntemler

Yeni çıkan arılar göğüs kısmında kırmızı, beyaz ve yeşil renkli organic etiketleme reçinesi kullanılarak işaretlendi ve sabitlendi (Honig Müngersdorff; Scheiner v.d. 2013). Etiketleri doğru bir şekilde ayarlamak için, her arının kovana girmeden önce kısa bir süre serbestçe hareket etmesine izin verildi.

Etiketlemeden sonra, etiketli arılar bir şişeye toplandı, şeker solüsyonu püskürtüldü ve video ile izlenen bir arı kovanına sokuldu. Arılara şeker solüsyonu yaymanın amacı, yeni arıları istilacı olarak düşündükleri için koloninin saldırısına uğramalarını önlemekti. Arılar vücutlarında şeker solüsyonu içeriyorsa, yaşlı arılar yeni arıların besin kaynağı hakkında bilgi sahibi olduğunu varsayarlar, dolayısıyla onlara saldırmazlar; bunun yerine yapılan sallanma danslarını izler ve besin alış veriş etkileşimini artırır (Diaz v.d. 2007).

Başlangıçta, arılar kovandan besleyici A [FA] 'ya yaklaşık bir hafta boyunca eğitildi (yaklaşık 30-50 arı). Güneş istikamet açısı dikkate alınarak FA, kovandan 251 metre uzaklıkta konumlandırıldı. Arılara besleyicide %30-50 şeker solüsyonu verildi. Eğitim tamamlandıktan sonra, belirli bir süre içindeki yiyecek arama gezileri sayısı için etiketli arıları kaydedildi. Besleyicilere eşit, farklı şekillerde şeker solüsyonları veya şekesiz su verildi yayılmacı arılar test edilerek ve ziyaretleri kayıdedildi.

Yukarıda belirtilen durumların sağlanması sırasında, etiketli arılar tespit edildi (kimlik numaraları aracılığıyla). Belli bir besleyiciyi belirli bir dönemde (her 10 dakikada bir) ziyaret eden arıların sayısını ve her iki besleyicide de geliş zamanlarını not edildi. Ayrıca, her iki besleyicideki her koşul için veriler 1 saatlik bir süre boyunca toplandı.

FA ve FB'nin yanı sıra, izleme sisteminden ve arı kovanının çıkış-giriş kapısından arı verileri not edildi. (a) etiketli arıların kimliği, (b) arının kovan kapısına geliş zamanı ve (c) arının kovandan ayrılış saati gibi bilgileri kaydedildi. Tüm veriler sabah ve akşam saatlerinde toplandı.

Sonuç

Bu çalışmada bir beslenme kaynağındaki farklı seviyelerde besin zenginliğinin (%10, %30 ve %50 şeker çözeltisi ve ödülsüz durum) ziyaretleri için yayılmacı arı sayısını etkileyip etkilemediğini ve önceki deneyimlerin arıları yiyecek aramaları için nasıl etkilediğini araştırıldı. Daha fazla arı, besin açısından zengin kaynakları ziyaret etmeye devam etti. Ancak düşük şekerli bir solüsyonu ziyaret eden arılarla karşılaştırılmasa da, daha yüksek şekerli solüsyonu ziyaret eden arıların sayısı zamanla azaldı. Bununla birlikte, besin zenginliğindeki azalma, arıların sayısında kademeli bir düşüşe neden oldu, ancak gıda bakımından zengin kaynaklarla ödüllendirilmese bile, birkaç gün boyunca beslenme alanlarını ısrarla ziyaret ettiler. Arıların gezi süresi açısından yiyecek arama etkinliği de önceki ziyaretlerin deneyimleriyle arttı. Sonuç olarak, arılar artık besin sağlamayı bırakan deneyimli beslenme alanları ile hatırı sayılır bir bağlanma sergilediler ve bu deneyimle birlikte yiyecek arama gezisinin süresi azaldı.

Yayılmacı arılar besin açısından zengin kaynaklar sunan beslenme alanlarını ziyaret etmeye devam ettiler. Aynı zamanda, gıda zenginliğinin azalmasıyla, o beslenme alanını ziyaret eden yayılmacı arı sayısı da azaldı. Yine de dikkate değer olan şey, yayılmacı arılar yiyecek bakımından zengin kaynaklarla ödüllendirilmeseler bile, yiyecek arama gezilerine birkaç gün devam etmeleridir.

Bu çalışma, arıcılara, arı kovanlarının maksimum bal verimi elde etmek için artırılmış bir nektar seviyesine gore bölge değiştirmede karar vermelerini ve aynı zamanda daha etkili tozlaşma için bölgede bitki örtüsü modelini belirlemeye karar vermelerini önermektedir. Ayrıca sonuçlar, seyahat süresi açısından arıların yiyecek arama etkinliğinin önceki ziyaretlerin deneyimleriyle artacağını ortaya koymaktadır. Son olarak, mevcut çalışma, günün saati ile arı kovanı dışında (yiyecek arama) harcanan zaman oranını karşılaştırıp karşılaştıramayacağımız konusunda gelecekte bir araştırma yapılmasını önermektedir.

INTRODUCTION

Foraging in animals is performed in a dynamic environment where accessibility of food is neither exclusively predictable nor random in time or space (Mobus and Fisher 1999). It is eminent that animals usually revisit the previous food sources (i.e., experienced food sources) and give up those who become unrewarding (Van Gils et al. 2003). For example, bumblebees (*Bombus impatiens*) stop visiting depleted food sources to search for the alternative rich food sources, and they do it more rapidly than honeybees (Townsend-Mehler et al. 2011). Social insects do not attach blindly to merely one approach. If experienced insect foragers are unrewarded from their known food sources, they continue following social location information for unknown but rewarding food sources and quit tracking the private location information (Grüter and Ratnieks 2011, Smolla et al. 2016).

The dynamics in the bee population at a particular floral cover depend on richness at the feeding site (Seeley 1995). The handling period of the flowers varied among the Turkish honeybee subspecies (i.e., *Apis mellifera caucasica, A. m. carnica, and A.m. syriaca*) and amplified with the presence of a particular quantity of the reward. Moreover, foragers of the subspecies mentioned above had a more significant net gain when looking in on flowers with consistent rewards (Cakmak et al. 2010, 2001). That is why honeybee colonies make decisions for their rates of recruitments as well as abandonment to feeding sites relying on the energy input (i.e., richness level) found at feeding source (Seeley et al. 1991). Similar information was described by Fernández et al. (2003) that the activation in the proportion of honeybee foragers depends on the rate of reward offered to them. Those honeybee foragers that trace a rich food source they rapidly learn spatiotemporal memories, which permit them to trip back to this particular site on the following days. Bees also exhibit significant persistence at the feeding site that quit proving rewards. Moreover, the decision to stop visiting that feeding site relies on the food richness the forager experienced while the site was rewarding (Toufailia et al. 2013). There is also another view by some researchers that honeybees again return to previously experienced food sites even after these having no reward anymore (Grüter and Ratnieks 2011, Moore et al. 2011). Similarly, another research finding articulates that experienced honeybees (*A. mellifera* L.) can retreat to previous profitable food sites after the time of short-term scarcity caused by unfavorable weather. According to these findings, activation of the experienced foragers to revisit the past-profitable food sites were performed due to the food scents brought back to the colony by other foragers (Beekman 2005).

Foraging performance and the frequency of trips enhance through the experience (Klein et al., 2019). Dukas (2008) and Schippers and M.-P. (2006) also endorsed the view which describes that the progress in the performance of honeybee foraging results with the experience. No doubt, the animals that travel to multiple foraging sites they have to face some hurdles in finding an exact route. But as they (i.e., bumble bees) learn about the shortcut paths with experience, their flight duration and distance become reduced (Woodgate et al. 2017). Studies mentioned above have stated that the foraging efficiency of bees enhances with the foraging experience. Still, no literature is found anywhere about the exact duration required for each trip with enhancing experience in honeybees (*A. mellifera*). That is why we tested how the trip duration changes with different days of experience. We reconfirmed it in *A. mellifera* along with the exact period of the foraging trips for a particular distance and remained successful in obtaining similar results (decrease in trip duration with experience) in our current investigation.

One of the primary aims of this study was to explore whether or not the different levels of food richness or rewards at a feeding source affect the number of *Apis mellifera* foragers to visit food source site once the conditions are switched to unrewarding. Moreover, another aim was to see how the previous foraging trip experiences affect foragers in their foraging duration and number of foraging trips. Regarding our first aim, we hypothesized that the switching of conditions from high to low level of food richness at an experienced feeding site would result in a gradual reduction in the number of visits performed by forager bees. Moreover, concerning our second aim, we predicted that the foraging efficiency of bees would increase (i.e., decrease in trip duration) with the experiences of the previous visits.

MATERIALS AND METHODS

Obtaining newly emerged bees, and their labeling

Honeybee brood frame was obtained from the apiary of the Silkworm & Bee Research Institute of Yunnan Academy of Agricultural Sciences. Newly emerged bees were collected in a bowl/container. After that, we started labeling bees with number tags on their thoracic part. Note that the number tags were in three different colors: red, white, and green, and were fixed on bees by using organic tagging resin designated as Shellac (Honig Müngersdorff; Scheiner et al. 2013). To correctly set the tags, each bee was allowed to move freely for a short time before their introduction within the beehive.

Introduction of tagged bees within the beehive

After tagging, the bees were collected in a bottle that was widely opened from its back and had a narrow circular hole where it can be screwed up with its lid. The sugar solution was sprayed on the bees collected in that bottle via its opened portion. Later, bees were introduced within a video-monitored beehive. The introduction of bees was done through a pipe connected between a bottle's holes and the central beehive monitoring system (Fig. 1). The purpose of spreading sugar solution on bees was to prevent them from being attacked by the colony as they think new bees as invaders. If bees contain sugar solution on their body, then old bees assume that the new bees have information about the food source, hence don't attack them; instead, follow waggle dances and increase trophallaxes interaction (Diaz et al. 2007).

Training and feeding of bees on Feeder A

In the beginning, bees were trained (about 30-50 bees) from beehive (N: 23.52608°; E: 103.39670°) to the feeder A [FA] (N: 23.525457°; E: 103.39908°) for about a week. Considering the effect of solar azimuth, FA was positioned (Fig.1) at a distance of 251 meters from the beehive. Bees were provided with a 30-50% sugar solution on the feeder. To allow the colony's bees to feed on solutions, firstly, we put the feeder close to the main hive. Some of the forager bees from the colony were picked and fed them sitting close to the feeder. Subsequently, we went on relocating the feeder from one point to another for training the bees to a distance of 251 meters. Once the training was accomplished, we started registering tagged bees for their number of foraging trips within a particular time.

Installation of Feeder B, and data collection

Feeder B was installed (N: 23.525295°; E: 103.39903°) (Fig. 2) nearby FA. Multiple situations on both feeders were provided. For the first situation, FA was supplied with a 30% sugar solution at the first session. In comparison, 50% of this solution at another session. For the second situation, both the feeders (FA & FB) were provided with 50% of the sugar solution at the same time. For the third situation, FA & FB were supplied with 30% and 50% of the sugar solutions, respectively. Moreover, for the fourth situation, FA was provided with a 30% sugar solution, and FB was supplied with a 50% sugar solution + 100% pure anise seed essential oil scent (Phutawan: Thailand). In the case of the fifth situation, FA was provided with a 10% sugar solution, and FB was supplied with a 50% sugar solution. Lastly, in the sixth situation, FA was unrewarded with a sugar solution (containing merely pure water), while FB was provided with the same concentration (50%) of the sugar solution.

During the provision of situations mentioned above, labeled bees were identified (via their ID numbers). We noted the number of bees visited a particular feeder at a certain period (within every 10 min.) and their time of arrival on both the feeders. Note that data with three replications of each situation, as mentioned earlier, were determined. Moreover, data for each condition on both feeders were collected for a 1-hour duration.

Data collection from the central beehive

Besides FA and FB, data of bees were noted from the monitoring system and on the exit-entry gate (Fig. 1) of the beehive. We registered the information like (a) identification of tagged bees, (b) time of the bee's arrival on the beehive gate, and (c) time of the bee's departure from the beehive. All the data were collected for an hour duration for morning and evening time.

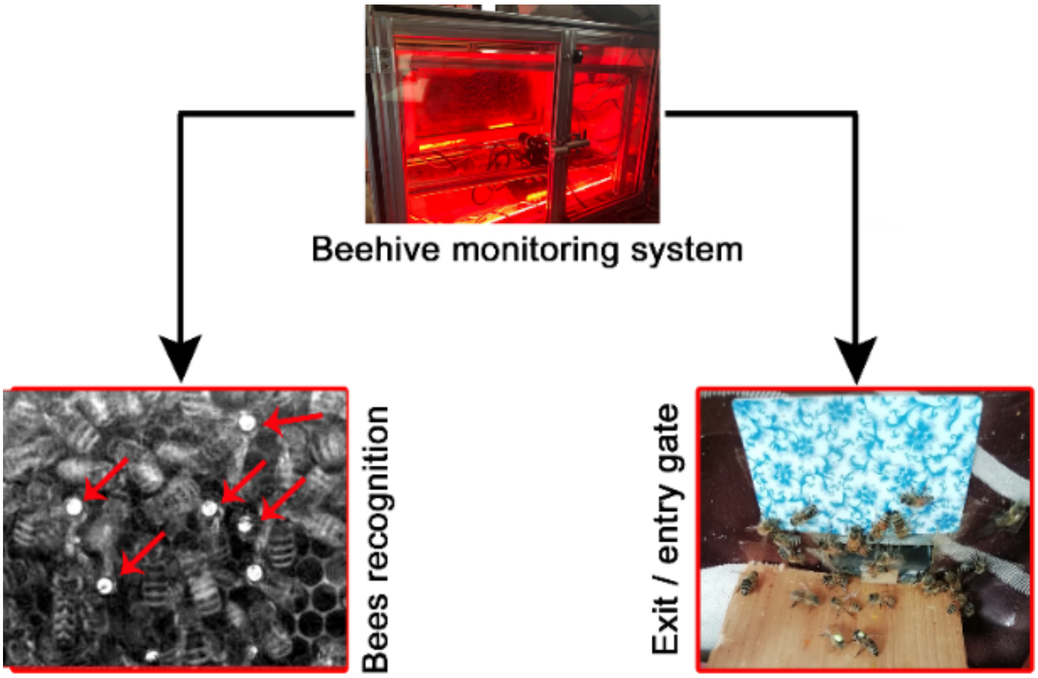

Figure 1: Monitoring system for recognition of labeled bees. Red arrows are directing toward the tagged bees that were video recorded within the beehive. In contrast, the departure and arrival of forager bees were noted on the exit/entry gate of the beehive.

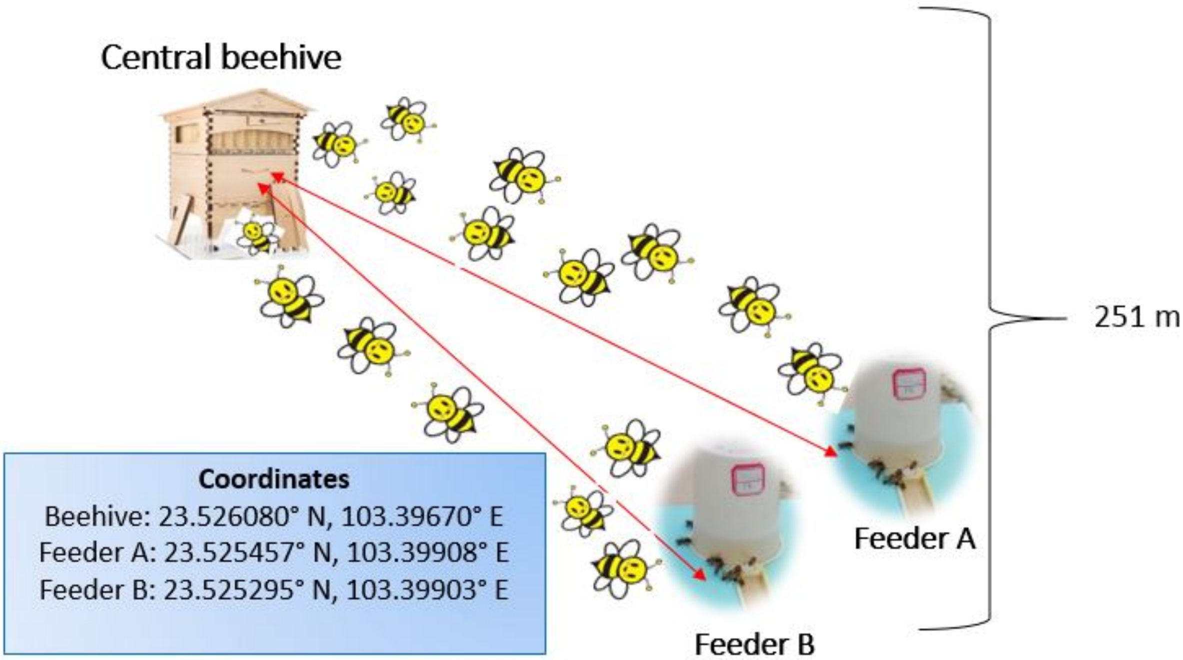

Figure 2: Schematic illustration presenting the directional arrangement of beehive and feeding sites (FA and FB).

Data analysis

Data were analyzed to check the foraging behavior of bees against the effect of food richness (10-50%) by using One-Way Repeated Measure ANOVA. While the comparisons were tested using the Generalized Linear Model (GLM). Besides, to test the effect of experience on honeybee foraging trips (i.e., duration), we calculated the time difference of bee trips between the feeders and the central beehive. All the statistical data were analyzed by R version 3.5.3 (R Development Core Team 2003).

RESULTS

Levels of food-richness effect on bee's foraging

In the first experiment, even with little variability in the first 15 minutes, the activity of forager bees fed on a 50% sugar solution remained higher than bees fed on a 30% sugar solution (Fig. 3). Foraging action was found increasing with an increased level of food richness. ANOVA showed a significant overall treatment effect on foragers fed on levels of food richness (df = 1; F = 7.07; bees with food richness (F) = *p* = 0.0120). Moreover, the number of foragers bees with time also shown significant effect (bees with time (T) = F= 89.1; df = 1; *p* = 0.01; Fig. 3). Regardless of comparison with the number of bees visiting a 30% sugar solution, the bees visiting a 50% sugar solution decreased with the time (Fig. 3).

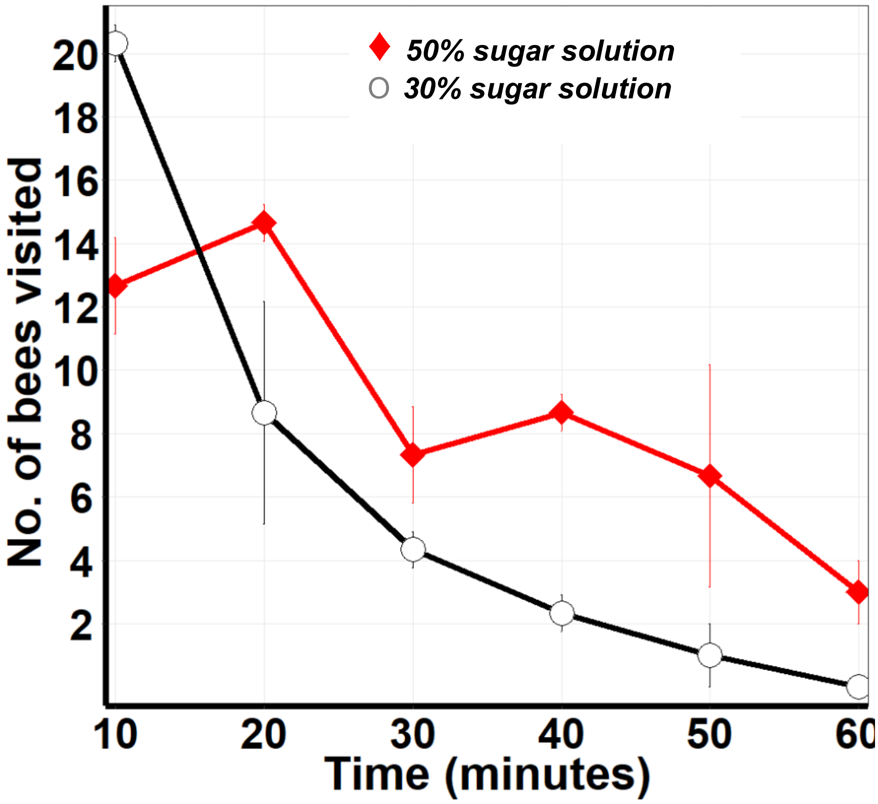

Figure 3: Variations in the number of bees visiting FA (containing different levels of food richness) at different time intervals: Redline in the graph is showing variation in the number of bees at 50% sugar solution, while the black line is showing this variation at 30% sugar solution.

In the second experiment, the data we took from both the feeders with the same concentration of sugar solution (50%) showed that the number of bees visiting FA versus those visiting FB increased in the first half an hour but then started decreasing from about 35 to 60 min. The overall effect of food richness on bees was highly significant (df = 1; F = 14.6; p = 0.00; Fig. 4a). Regarding our third experiment, the overall treatment effect of food richness on forager bees was highly significant (df = 1; F = 84.4; p<0.001; Fig. 4b). The variation in the number of bees with the time was also calculated as highly significant (df = 1; F= 7.59; p<0.01; Fig. 4b). But, with both the food-richness and the time, this variation was calculated as non-significant (df = 32; F = 1.90; F: T= p = 0.18; Fig. 4b).

In our fourth experiment, it was interesting to observe that more number of forager bees visited less experienced feeder “FB” for the first 15 minutes. But, after this duration, a gradual increase in the number of bees at FA was noticed, which may be due to the effect of anise seed oil scent, which was added with sugar solution offered at feeder B. Moreover, statistical calculations for bees exhibited a highly significant impact with the levels of food richness (df = 1; F = 3.40; p= 0.00; Fig. 4c), while non-significant effect with the time (df = 1; F = 3.40; p= 0.08; Fig. 4c).

The situation we provided in our fifth experiment (10% sugar solution at FA, and 50% at the FB) yielded different results. Overall results of the given situation exhibited that even a decrease in the concentration of sugar solution could not decrease the number of bees at FA as compare to FB, offering a more concentrated sugar solution. Analysis showed non-significant overall effects on foragers with the food richness (df = 1; F = 0.00; p= 0.95; Fig. 4d), time (df = 1; F = 0.60; p= 0.40; Fig. 4d) as well as between both (df = 1; F = 1.80; F: T= p= 0.20; Fig. 4d).

In the sixth and last experiment, it was the first time when we observed that there were significantly fewer bees visiting FA. Still, a significant upsurge in the number of bees was noted at FB during the whole period of the experiment. Hopefully, this shift was due to non-rewarding situations at FA with the fact that when the bees face such cases, they start looking for other profitable food options. Also, the statistical values for the number of bees concerning food richness and time presented higher significance (df = 1; F = 13.10; p<0.001; Fig. 4e).

Foraging performance increases with experience

Regarding the effect of experience on honeybee foraging duration, we found exciting results (Table 1). In the initial days of the experiment, foragers exhibited a long period to complete a one-way trip between hive to feeders. But with the time (as they got some experience of food source locations: i.e., FA & FB), the duration of one-way foraging trip of forager bees were started decreasing gradually (Fig. 5). For example, trips of a forager bee (ID no. Red82) were noted on days 1, 5, and 6, the probable duration of each one-way trip for this forager was 19, 5, and 3 minutes respectively. Moreover, the gradual decrease in time of foraging trips was also noticed in another active forager (ID no. Red 53), the probable duration of each trip for day 1-, 2-, and 3- were 19 & 12, 11, and 2 minutes respectively. Some other foragers that visited feeders multiple times in different days also showed a similar decreasing pattern in foraging duration (Table 1). And those foragers that we could recognize merely one time on a feeder they also covered their trips within less time as compare to those foragers that visited in previous days. Statistical analysis confirmed that the decrease in trip time with the experience is highly significant (df (between days) = 4; df (within days) = 25; F = 6.24; p = 0.001; Fig. 5).

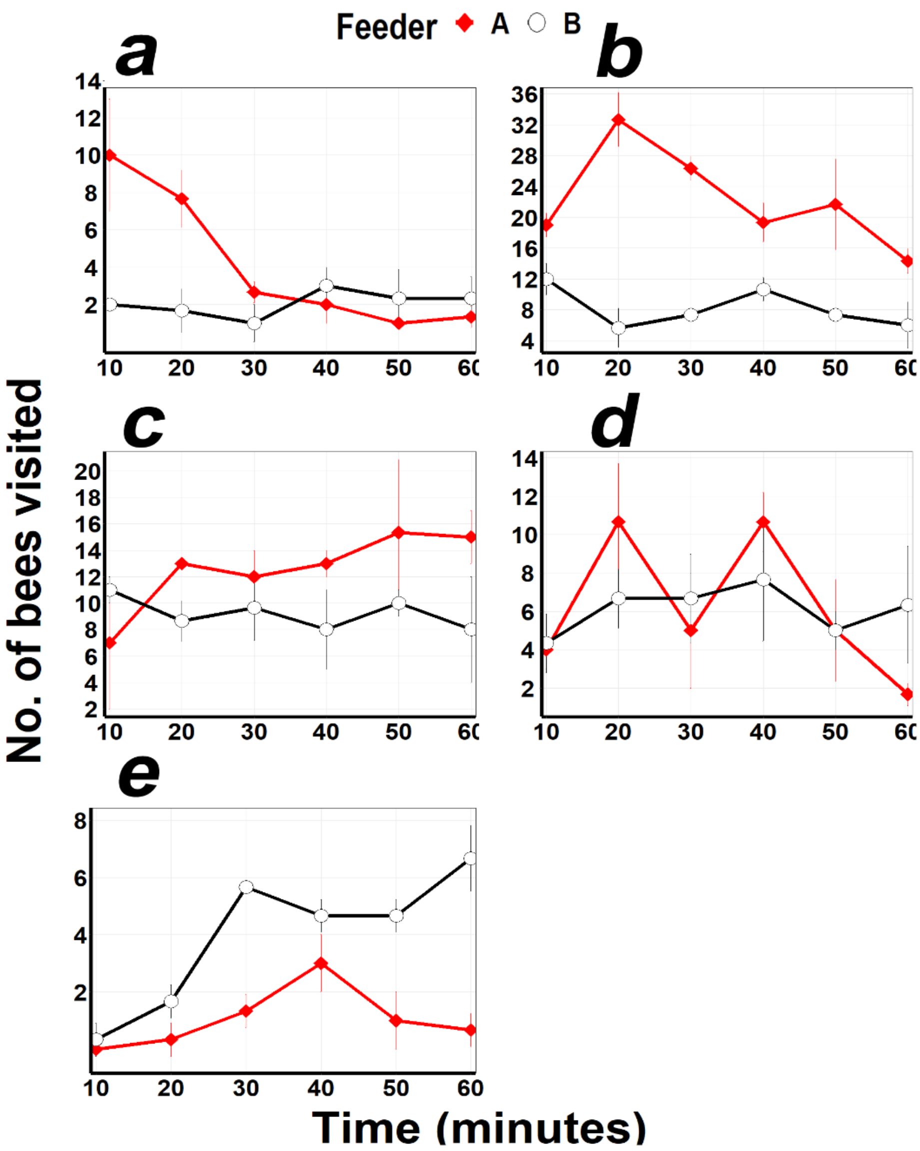

Figure 4: Graphs exhibiting variations in the number of bee foragers visiting FA (◆) and FB (○) (containing multiple levels of food richness) at different time intervals: a) FA and FB both offering 50% sugar solution. **b)** FA and FB are offering 30% and 50% sugar solutions, respectively. **c)** FA offering 30% sugar solution, while FB is offering a 50% sugar solution + anise seed oil scent. **d)** FA and FB are offering 10% and 50% sugar solutions, respectively. **e)** FA and FB are offering unrewarding conditions (merely water) and a 50% sugar solution, respectively.

Table 1: Fluctuations in foraging of bees with the experience: data exhibit the duration of one-way foraging trip (between hive and feeders) of some bees in different days

Days	Bee IDs	Time of arrival on FA (00:00 am/pm)	Time of arrival on FB (00:00 am/pm)	Depart from hive's exit/entry gate	Arrival on hive's exit/entry gate	Probable duration (min.) for a one-way foraging trip
1	Red 82	10:33 am			10:52 am	19
1	Red 57	10:31 am			10:40 am	9
1	Red 53	10:30 am			10:44 am	14
1	Red 29	11:03 am		11:01 am		2
1	Yellow 10	2:56 pm			3:10 pm	14
1	Red 53	3:40 pm		3:52 pm		12
2	Red 73	10:00 am		9:57 am		3
2	Red 53	9:56 am			10:07 am	11
3	Red 60	4:46 pm		4:38 pm		8
3	Red 19	4:41 pm		4:34 pm		7
4	Red 82		10:25 am	10:20 am		5
4	Red 53		10:19 am	10:17 am		2
4	Red 43	10:04 am		9:59 am		5
4	Red 46	4:40 pm			4:27 pm	13
5	White 96	10:25 am		10:19 am		6
5	Red 53	10:51 am		10:46 am		5
5	Red 99		4:36 pm	4:34 pm		2
5	Red 82		4:37 pm	4:34 pm		3

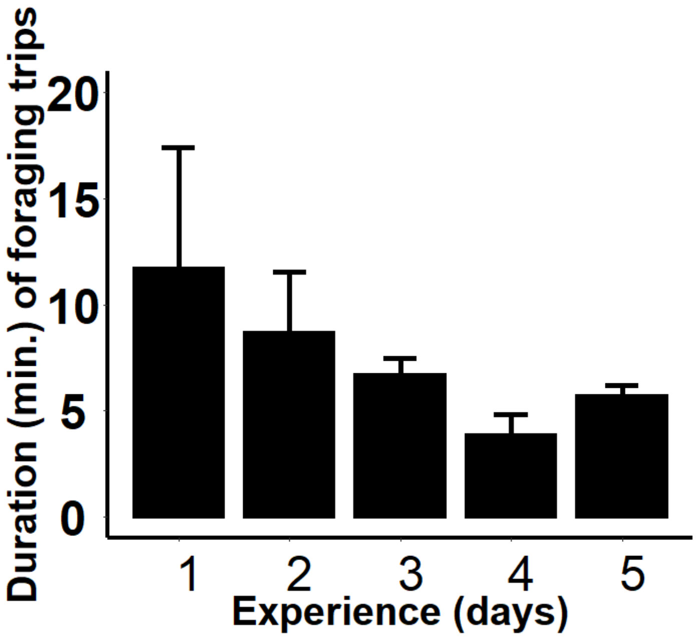

Figure 5: Duration of one-way foraging trips of *A. mellifera* affected by the experience

DISCUSSION

As animals travel through different environmental conditions to seek resources, they have to face multiple challenges of how best to deal with their time as well as energy among accessible opportunities. In the case of the natural environment, animals must frequently select among a group of behavioral choices available to them to react efficiently to changes in food resources (Townsendmehler 2010). Because of different assumptions regarding bee foraging to recently unrewarding conditions (i.e., with depleted food sources) at the food source, we raised a question to find its answer. The primary purpose of our inquiry was to explore whether or not the different levels of food richness or rewards at a feeding source affect the number of forager bees to visit this location once the conditions are switched to unrewarding.

The behavior of honeybee foragers largely depends on the level of food richness they find at their feeding locations (Frisch 1965). The results revealed that the persistence in honeybee foraging to the depleted sources is considerably affected by their previous experience of that particular site as well as its high level of food richness. Toufailia et al. (2013) describe that the bees continue their visits to unrewarding or empty feeders up to a week after merely a short duration of training access. Although the overall number of forager bees in our experiment decreased with depleted level of food richness at the training site (FA), even then, according to the result as mentioned earlier, some bees did not quit visiting that particular site for certain days. More number of bees inevitably visited high rewarded feeders (Fig. 3 & 4) as compare to low rewarding feeders. According to the results of Cakmak et al. (1999), the action of forager bees altered when they were presented with different reward frequencies associated. But, regardless of comparison, the number of bees visiting high rewarding sites (i.e., 50% sugar solution) decreased in relation with the time (Fig. 2) which may be due to the fact that highly concentrated sugar solutions are viscous, and crop loads are negatively correlated with the viscosity of the solution (Nicolson et al. 2013). It also may be since honeybees do not persistently behave as projected via simple energy maximization principles; instead, uniqueness in choice rises at the time when visiting obstacle becomes more strenuous due to the enhanced complexity of the problem (Cakmak et al. 2009)

In a series of variant experiments, it was determined that the time course of extinction of currently unrewarding sources is mainly reliant on the amount of experience gained at a particular food source (Moore et al. 2011). That is why, in our current experiment, we observed more number of bees with a gradually decreased level of food richness at the experienced feeder (FA) versus less experienced feeder (FB) with a high level of food richness. It is a general assumption that time memory in honeybees promptly loss if not reinforce daily. Hence, it permits foragers to shift rapidly from non-rich to rich food sources. Therefore, a characteristic in an animal is also reported, which describes that they may alter their behavior according to their understanding of risk, including predators (Sharif et al. 2020) or unprofitable food source conditions (Tan et al. 2015). We observed a sudden decrease in the number of bees at FA, which switched offering depleted food source, while a relative increase in the number of bees was observed at FB switched offering rich food source. Variant levels of food richness exploited by a single active forager have an impact on the performance (frequency and intensity) of its recruitment-linked behaviors. Within the beehive, such variation defines a distinctive inspiration of hive-mates having diverse thresholds to depart from the hive (Fernández et al. 2003). From an example of a field plant (i.e., *Brassica campestris* var. *toria*), the results propose that cultivars offering rich caloric rewards to bees have a competitive advantage over others in terms of appealing bee foragers and, subsequently, in pollination (Abrol 2007).

Multiple factors have been reported that affects foraging efforts as well as foraging distance in bees. These factors include experience, wing damage, environmental factors, and internal condition of colonies (Klein et al. 2019, Higginson et al. 2011, do Nascimento and Nascimento 2012, Barbosa et al. 2016). It had been expressed that individual honeybees increase their foraging performance with experience. Those studies verified the foraging behavior of bees in their career, but it focused merely on individual bee level (Schippers et al., 2006, Dukas 2008). Recently, Klein et al. (2019) explored foraging activity and the foraging performance of a massive number of honeybee foragers (*A. mellifera*) by using an automated behavioral tracking system. They concluded with the remarks that bees at the colony level also improve their foraging performance and frequency of their foraging trips via experience. According to Durisko et al. (2011), in the natural environment, honeybees exhibit gradual improvement in their foraging performance parallel to the typical pattern of performance found in the lifespan of various animals, including humans. They also stated that the longstanding improvement in the performance of bees under the natural environment might be instigated by certain factors like spatial orientation, locating the best rewarding plant species, flower patches, etc. Peat and Goulson (2005) explored *Bombus terrestris* for the rate of foraging trips. They ensured that the rate of foraging trips varies with the experience. In the first few trips, they observed a low foraging rate but later increased with the experience. That increase in foraging rate was smaller initially, but after nearly 30 trips from the nest, they observed further improvement in foraging rates. As in our current experiment, the duration of every one-way foraging trip gradually decreased with the following days; therefore, we also affirm the results of previous studies that the performance of honeybees in foraging increases with the experience. Which extent of a high level of sugar concentration (viscosity) causes total foraging avoidance? Besides food richness and experience, can we compare the time of the day with the rate of time spent outside (foraging) the beehive? These are the essential questions that can be explored in future investigations.

CONCLUSION

Bee foragers keep on visiting that feeding sites offering food-rich source. But, regardless of comparison with the number of bees visiting a low food-rich source, the bees foraging towards a highly food-rich source decrease with the time. Simultaneously, with the reduction in food richness, the number of foragers visiting that feeding site also reduced. Still, the notable thing is they continue their foraging trips for several days, even if they are un-rewarded with food-rich sources. It is a fantastic behavior in bees that help re-allocation of colony's foragers in altering natural settings. This study suggests beekeepers for their decision about the replacement of their apiaries to the fields with an augmented level of nectars for getting maximum honey yield, and also help to decide setting vegetation pattern in the area for providing full opportunities for pollination. Furthermore, results utter that our prediction: foraging efficiency of bees in terms of trip duration will increase with the experiences of previous visits, proved correct. Depending on the level of expertise, the *A. mellifera* requires a 19 to 2 minutes duration for a one-way foraging trip to 251 meters. Lastly, the current study confers the implications for future investigation on whether we can compare the time of the day with the rate of time spent outside (foraging) the beehive. Which extent of a high level of sugar concentration (viscosity) causes total foraging avoidance by honeybees? These are suggested questions for further exploration in upcoming studies by the researchers.

ACKNOWLEDGMENTS

Firstly, we are highly thankful to the Silkworm & Bee Research Institute of Yunnan Academy of Agricultural Sciences for allowing us to conduct our experiments, providing services of beekeepers, availability of bee colony, and some other materials. Secondly, we highly acknowledge the contribution of Mr. Hu Zongwen in providing bee tags and help to mark bees. Lastly, I (the corresponding author) say special thanks to the Chinese Academy of Sciences for providing me the "CAS-TWAS Scholarship" for my doctoral study. The results of the current study are expected to be a part of Muhammad Zahid Sharif's doctoral thesis.

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