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ARAŞTIRMA MAKALESI / RESEARCH ARTICLE

PREFERENCE BEHAVIOR TOWARDS MINERAL ELEMENTS BY HONEYBEE

Bal Arısının Mineral Elementlere Yönelik Tercih Davranışı

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ABSTRACT

The study was conducted to investigate honeybee preferences for various micronutrients and their concentrations. throughout the summer of 2021 at the Plant Protection Research Institute, ARC, Giza, Egypt, specifically at the apiary of the Bee Research Department. Forager bees showed strong avoidance responses only to high mineral concentrations (2, 1, 0.5%, and 0.25%) for sodium, potassium, calcium, and magnesium chloride. On the other hand, Foragers bees recorded a high visitation number in low concentrations (0.1, 0.05, 0.025 %, and 0.0125%) for 4 minerals and tap water. The honeybee prefers dilute sodium chloride and its low concentrations (0.0125%), which recorded a higher visitation number among all mineral concentrations under the study. In contrast, the bees exhibited no discernible preferences for the calcium chloride solutions with a low visitation number of 0.1 and 0.05% compared with tap water. The visitation numbers are similar in magnesium and potassium at 0.05, 0.025, and 0.0125% but higher than tap water. The solution was consumed at a concentration of 0.0125 after 139 minutes, a concentration of 0.025 after 142.5 min., and a concentration of 0.05 after a time had passed 157.5 min. The preference factor for NaCl solution was recorded at a concentration of (0.0125) Thus, the bees' preference for this concentration is higher than their preference for tap water. The lowest preference factor (0.4) was recorded with a $CaCl_2$ solution with a concentration of (0.1). low consumption ratios were recorded for 0.0125% potassium chloride (indicating a preference for the test solution), and higher consumption ratios were reported for 0.1% calcium chloride (indicating avoidance of the test solution).

Key Words: Honeybee, Preference, Elements, Solutions, Concentrations

ÖZ

Çalışma 2021 yazında çeşitli mikro besinler ve bunların konsantrasyonlarında bal arısı tercihlerini araştırmak için Mısır'ın Giza kentindeki ARC Bitki Koruma Araştırma Enstitüsü'nde Arı Araştırma Bölümünün arı kovanlarında gerçekleştirildi. Yayılmacı arılar yalnızca sodyum, potasyum, kalsiyum ve magnezyum klorür için yüksek mineral konsantrasyonlarına (%2, 1, 0,5 ve 0,25) güçlü kaçınma tepkileri gösterdi. Öte yandan, toplayıcı arılar için 4 mineral ve musluk suyu için düşük konsantrasyonlarda (%0,1, 0,05, 0,025 ve 0,0125) yüksek bir ziyaret sayısı kaydedildi. Bal arısı için seyreltik sodyum klorür ve onun çalışma kapsamındaki tüm mineral konsantrasyonları arasında daha yüksek bir ziyaret sayısı kaydeden düşük konsantrasyonlar (%0,0125) kaydedilmiştir. Buna karşılık arılar, musluk suyuyla karşılaştırıldığında %0,1 ve %0,05 gibi düşük bir ziyaret sayısına sahip kalsiyum klorür çözeltileri için fark edilebilir bir tercih sergilemedi. Ziyaret sayıları magnezyum ve potasyumda %0,05, 0,025 ve 0,0125'te benzerdir, ancak musluk suyu ziyaret sayılarından daha yüksektir. Çözelti, 139 dakika sonra

0,0125 konsantrasyonda, 142,5 dakika sonra 0,025 konsantrasyonda ve 157,5 dakika geçtikten sonra 0,05 konsantrasyonda tüketildi. NaCl çözeltisi tercih faktörü (0,0125) konsantrasyonda kaydedilmiştir. Dolayısıyla arıların bu konsantrasyonu tercihi, musluk suyu tercihinden daha yüksektir. En düşük tercih faktörü (0,4), konsantrasyonu (0,1) olan bir $CaCl_2$ çözeltisi ile kaydedildi. Bunun yanında %0,0125 potasyum klorür için düşük tüketim oranları kaydedilmiştir (test solüsyonunun tercih edildiğini gösterir) ve %0,1 kalsiyum klorür için daha yüksek tüketim oranları rapor edilmiştir (test solüsyonundan kaçınıldığını gösterir).

Anahtar Kelimeler: Bal Arısı, Tercih, Elementler, Çözümler, Konsantrasyonlar

GENİŞLETİLMİŞ ÖZET

Amaç: Bu deney, bal arısının 8 konsantrasyondaki sodyum, potasyum, kalsiyum ve magnezyum klorür çözeltileri ve musluk suyu tercihini, birincil tercih deneyleri olarak 90 dakika boyunca gözlemlenen ortalama bal arısı ziyareti sayısına göre ayrı ayrı değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntem: Tablo 1'den, yiyecek arayan bal arılarının yalnızca sodyum, potasyum, kalsiyum ve magnezyum klorür için yüksek mineral konsantrasyonlarına (2,0, 1,0, 0,5 ve 0,25) güçlü bir tepki göstermediği açıktır. Öte yandan yiyecek arayan arılar için dört metalin ve musluk suyunun düşük konsantrasyonlarında (%0,1, %0,05, %0,025 ve 0,0125) çok sayıda ziyareti kaydedildi. Bu nedenle, daha yüksek konsantrasyonlar ana tercih çalışması denemesinin dışında tutuldu. Arı ziyaretlerinin ortalama sayısına göre mineral konsantrasyonu tercihleri, NaCl, KCl, $MgCl_2$ ve **$CaCl_2$** için Tablo (2)'de gösterilmektedir.

Bulgular ve Sonuçlar: Bulgular, çalışma sırasında bal arılarının tüm tuz çözeltilerinin tüketiminin önemli ölçüde değiştiğini göstermektedir. Genel olarak tuz çözeltisi tercihi, tuzun türüne ve konsantrasyonuna göre belirleniyordu. Bal arısı seyreltik sodyum klorürü ve düşük konsantrasyonlarını (%0,0125) tercih etmekte, bu da çalışma kapsamındaki tüm mineral konsantrasyonları arasında daha yüksek bir ziyaret sayısı kaydedilmesine neden olmuştur (52,1 ± 13,3). Ziyaret sayısı %0,1 ve %0,05 gibi düşük olan kalsiyum klorür çözeltileri ise musluk suyuna kıyasla arılar tarafından özellikle tercih edilmemiştir. Ayrıca, ziyaret sayıları ortalama olarak magnezyum ve potasyum bakımından %0,05, 0,025 ve 0,0125 ile benzerdir ancak musluk suyu ziyaret sayılarından daha yüksektir. Zaman tercihle ters orantılıdır. Arılar çözeltiyi ne kadar çok tüketirse tercihi de o kadar az olur. Arılar çözeltiyi ne kadar az tüketirse tercih de o kadar fazla olur. Bu süre dakika olarak tahmin edildi. Bal arıları musluk suyuna kıyasla NaCl'yi ve konsantrasyonlarını tercih eder. Bal arıları seyreltilmiş sodyum klorürü ve onun düşük konsantrasyonlarını tercih eder. Çözelti, 139 dakika sonra %0,0125 konsantrasyonda, 142,5 dakika sonra %0,025 konsantrasyonda ve 157,5 dakika geçtikten sonra %0,05 konsantrasyonda tüketildi. Arıların solüsyonu tüketmesi için en uzun süre, sodyum klorür solüsyonunun %0,1 oranında konsantre edildiği zamandı ve 163,5 dakikaydı. Potasyum klorür çözeltisinin konsantrasyonda (%0,1) tüketim süresi 171,0 dakikaya, konsantrasyonda minimum çözelti tüketim süresi (%0,0125) ulaştı. 123,0 dakikaydı. Aynı durum, en düşük tüketim süresinin düşük konsantrasyonlar için, en yüksek tüketim süresinin ise yüksek konsantrasyonlar için olduğu kalsiyum ve magnezyum çözeltileri için de geçerlidir. NaCl çözeltisi tercih faktörü (0,0125) konsantrasyonunda kaydedilmiştir. Dolayısıyla arıların bu konsantrasyonu tercihi, musluk suyu tercihinden daha yüksektir. En düşük tercih faktörü (0,4), konsantrasyonu (0,1) olan $CaCl_2$ çözeltisi ile kaydedildi. Ek olarak Şekil (2)'de %0,0125 potasyum klorür için düşük tüketim oranları kaydedilmiştir (test solüsyonunun tercih edildiğini gösterir), %0,1 kalsiyum klorür için daha yüksek tüketim oranları rapor edilmiştir (test solüsyonundan kaçınıldığını gösterir). Son olarak, sonuçlar, çalışma sırasında bal arılarının musluk suyuna kıyasla tuz çözeltisini daha güçlü bir şekilde tercih ettiğini ve bu tercihin türe ve konsantrasyona bağlı olduğunu, arıların minerallerle ilgilendiğini ortaya koymaktadır.

INTRODUCTION

Whether for humans or animals, water is the most essential component of existence and cannot be ignored. Bees, like other insects, consume water to quench their thirst and provide their bodies with the water they need for bodily reactions to keep them alive. As the temperature rises in the summer, as in months 7, 8, and 9 their need for water increases. (Khan et al. 2021)

Nectar, which has about 60% water by volume (Nicolson 2008), provides the water bees need. It has been observed that bees gather huge amounts of water throughout the summer to reduce heat stress and to maintain colonies at an ideal humidity level, which should not be less than 75% (Ellis et al. 2008), which is necessary for bee eggs to hatch without deformations and for the duration of the broods normal development.

An apiary with 100 colonies uses 350 liters of water per week, and a single hive typically uses half a liter of water per day while raising brood. The higher the temperature, the more water bees consume up to 3 liters per day in some cases. The bee needs five minutes to bring the water to the hive, dump it inside, and then store it in its body. The closer the distance and the hotter the environment, the more frequently it does this process 1 to 7 times each hour. (Abrol et al. 2012, Al-Kahtani et al. 2020, Chakrabarti et al. 2020)

No matter if it is surface, ground, or even rainfall collected in domestic wells, drinking water contains a variety of elements in the form of dissolved salts or suspended matter. It may be argued that calcium, magnesium, sodium, and potassium are the elements that are most concentrated in the majority of drinking water (Ricigliano 2020, Wright et al. 2018, Zhang and Xu 2015). They can be considered the four primary mineral components of drinking water. They are present in the form of salts that combine with sulfates, carbonates, chlorides, and other groups. Other elements, such as iron or manganese, or trace amounts of uncommon elements found in nature, such as cadmium, lead, and others, are present in water in smaller quantities (Hafeez et al. 2019).

According to research studies (Baumgartner and Roubik 1989, Bänziger et al. 2009, Ferry and Corbet 1996), sodium, magnesium, and potassium are important for the growth of larvae in honey bees. It is believed that salts from water may be a crucial component of the brood food provided by nurse bees (Herbert and Shimanukia 1978).

Perhaps because it is frequent and contains salts, honeybees prefer water runoff from cities or farms (Hooper, 1932; Butler, 1940). These preferences are not well understood, though. Honey bees have strong group-foraging preferences for water with particular salt concentrations, as demonstrated by (Butler (1940). Foraging bees are drawn to the presence of other bees due to their social facilitation (Avarguès-Weber et al. 2015), making it challenging to distinguish between group and individual preferences for foraging. Little progress has been made since Butler (1940) in our understanding of the salt preferences of water foragers. When salt concentrations rise to a point where drinking the water becomes unpleasant, or when other polluting chemicals, like heavy metals or nitrates, have concentrations that are too high, the problem of salts in drinking water arises (Adgaba et al. 2020).

Higher levels of potassium and phosphate in nectar can repel nectar foragers (Afik et al. 2006, Hagler et al. 2011), additionally, a high enough concentration of salt can act as a punishing stimulus (Abou-Shaara 2012, Letzkus et al. 2006). Individual water foragers' salt preferences, however, remain unknown. It is crucial to comprehend these salt preferences to comprehend honey bee biology and, possibly, to develop salt additions that would prevent bees from collecting agricultural water contaminated with dangerous xenobiotics (Adgaba et al. 2020).

Honeybees frequently gather water from various unfavorable places, including puddles on top of cow dung and sewage effluent and rainwater gutters loaded with decomposing organic debris. They avoid using the pure water sources that are available in the apiary for their usage (de-Sousa et al. 2022).

The bee automatically extends its proboscis to drink if the concentration is suitable. Phosphate may discourage nectar foragers since Nacl, $Mgcl_2$, and Kcl are crucial bee nutrients (Afik et al. 2006).

The study aims to determine which ingredients in water honeybee foragers prefer. It also seeks to identify the concentrations that appeal to and repel them. To discover salt concentrations in bee-collected water, the research also aims to study the behavioral mineral selection of honey bees.

MATERIALS AND METHODS

The current study was conducted throughout the summer of 2021. Forty colonies with open-mated hybrid queens of the same age in preparation for the experiment. The general micronutrient requirements of sodium chloride (NaCl), potassium chloride (KCl), calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$) were tested to see which the honey bees preferred in eight concentrations for each mineral (2.0,1.0, 0.5, 0.25, 0.1, 0.05, 0.025, 0.0125% w/v) and tap water as a compared solution (Lau and Nieh 2016). There were three to four preference assays conducted each week. For this, a 2-meter-long wooden table with salt solutions was set up. Tap water was also placed on the table for comparison, the distance between the water source and the colonies was 2 meters. Bees stand on the walls of the cup to drink water. A hundred (100) mL of the assigned solution was added to a plastic cup (125 mL) at the beginning of each trial, and the cups were then arranged randomly on the table each day. During the first trial, every mineral was placed individually in 8 concentrations. In the main preference experiment trial, the four minerals with different concentrations were placed randomly together in the table. The measurements were taken by continuously monitoring the bees throughout the day with a digital video camera Sony DSC-W810 (20.1 MPixels) placed 1 meter away from element solutions, The digital camera records the salt water and tap water data of the bees throughout the day via a memory card, throughout the summer, from mid-June to mid-September. All other water sources in the apiary area were closed the bees were guided to use these cups for drinking rather than looking for another source.

Test solutions contained different concentrations of NaCl, KCl, $MgCl_2$, $CaCl_2$ (ACS reagent grade compounds, 99.8% purity, Fisher Chemical in distilled water.

Primary experiments

This experiment aims to exclude solutions of elements that the bees do not prefer, through the total number of visits made to the solution within 90 minutes. We preferred an hour and a half because for the first 20 minutes, the bees are circling over the solutions and no decision on preference is made. The other hour, the bees decide on their preference, and during an hour and a half, the solutions are mostly available to bees. After that, a statistical analysis was performed for each solution element alone because the measurement was done at the element level in the primary experiment.

Main preference experiment:

In this experiment, solutions of elements were placed together 4 elements *4 concentration with tap water as compared to solution. It was repeated 15 times for 15 days.

Four concentrations of chloride salt solutions were stabilized in comparison to tap water using the following 17 treatments: hundred (100) ml of each concentration of 0.1%, 0.05%, 0.025%, and 0.0125 % w/v for NaCl, KCl, $MgCl_2$, $CaCl_2$, and tap water.

A digital camera recorded the number of worker bees visiting the solutions. The amounts of salt solutions and tap water consumed throughout the day from morning to afternoon are counted and used to track the bees' preferences for each treatment and the number of bees attracted to it.

To ascertain the honeybees' preference behavior, the locations of the solutions and their various concentrations varied daily.

Studying parameters:

1- Number of honeybee visitation observations per 90 minutes (Cairns et al. 2021).

2- different mineral solution concentrations in primary preference experiments.

3-The mean time (minute) for a honeybee to consume 100 mL of mineral solution.

4- Calculate the Preference index for bee visits **=**

$$\frac{\text{The number of visits for each solution}}{\text{The number of visits to tap water (as a control).}}$$

-When the preference factor equals one, the bees' preference for the element solution is equal to the bees' preference for tap water.

-When the preference factor is greater than one, the bees' preference for the element solution is greater than the bees' preference for tap water.

- But the preference factor is less than one, and the bees' preference for the element solution is weak compared to the control (tap water).

5- Calculate the preference index for solution consumption time =

$$\frac{\text{The time the bees consume 100 ml of the element solution}}{\text{The time the bees consume 100 ml of tap water (control)}}$$

That means the shorter the consumption time, the greater the preference.

6- Statistical analysis

Means were statistically evaluated using a completely random block design (RCBD) and a two-way ANOVA using the MSTAT program (Snedecor and Cochran, 1980) and Prisma software. To compare the data, Duncan's test was employed (Duncan, 1955).

Picture 1: Mineral preferences experiment table study

RESULTS

A. Primary experiments

Preference of foragers honeybees for different mineral concentrations individually

This experiment aims to evaluate the honey bee preference for sodium, potassium, calcium, and magnesium chloride solutions in 8 concentrations and tap water individually by the mean number of honeybee visits observed for 90 minutes as primary preference experiments. From Table 1, it is clear that forager bees showed strong avoidance responses only to high mineral concentrations (2.0, 1.0, 0.5, and 0.25%) for sodium, potassium, calcium, and magnesium chloride, with a significantly different response. On the other hand, Foragers bees recorded a high visitation number in low concentrations (0.1, 0.05, 0.025, and 0.0125%) for 4 minerals and tap water. Therefore, high concentrations were excluded from the main preference study experiment.

Table 1. The mean number of honeybee visitations observations per 90 minutes for eight mineral solution concentrations (%w/v).

Mineral concentrations	NaCl	KCl	$MgCl_2$	$CaCl_2$
2.0	2.0 ± 1.0	0.0 ± 0.0	0.7 ± 0.5	0.7 ± 0.0
1.0	7.0 ± 1.0	6.7 ± 0.6	4.0 ± 1.0	0.0 ± 0.0
0.5	6.7 ± 1.5	5.0 ± 3.0	11.7 ± 6.5	0.7 ± 0.6
0.25	36.7 ± 13.5	18.7 ± 7.5	34.0 ± 12.0	2.0 ± 2.0
0.1	61.7 ± 13.5	24.0 ± 2.0	48.0 ± 5.0	11.3 ± 1.5
0.05	43.7 ± 2.5	31.7 ± 0.6	73.7 ± 4.6	49.7 ± 6.5
0.025	48.7 ± 0.6[a]	40.0 ± 3.0	65.7 ± 7.5	31.0 ± 19.0
0.0125	23.0 ± 1.0	39.7 ± 0.6	59.0 ± 14.0	62.0 ± 1.0
Tap water	30.7 ± 1.5	29.0 ± 4.0	40.0 ± 13.0	92.5 ± 5.5
$LSD_{0.05}$	**8.9**	**4.5**	**11.7**	**9.6**

B. Main preference experiment:

1. Number of honeybee visitation observations

Mineral concentration preferences by the mean number of forger honey bee visits observed per 90 minutes are indicated in Table (2) for NaCl, KCl, $MgCl_2$, and $CaCl_2$ in four concentrations compared with tap water. The findings showed that during the study, honey bees' consumption of all salt solutions varied significantly. In general, one's preference for a salt solution was determined by the type and concentration of the salt. The honeybee prefers dilute sodium chloride and its low concentrations (0.0125%), which recorded a higher visitation number among all mineral concentrations under the study (52.1 ± 13.3). The calcium chloride solutions with a low visitation number of 0.1 and 0.05%, on the other hand, did not appear to be particularly preferred by the bees compared with tap water. In addition, visitation numbers are on average similar in magnesium and potassium at 0.05, 0.025, and 0.0125% but higher than tap water visitation numbers.

Table 2. The mean number of honeybee visitations observations per 90 minutes for four mineral solution concentrations (%w/v).

Salts	Mineral concentrations (w\v)				Tap water	LSD 0.05
	0.1	0.05	0.025	0.0125		
NaCl	35.6 ± 10.4 [c]	27.7 ± 7.1 [e]	45.2 ± 17.2 [b]	52.1 ± 13.3 [a]	24.5 ± 9.4	**10.9**
KCl	21.5 ± 8.0 [f]	32.2 ± 8.4 [d]	37.8 ± 14.6 [b]	37.8 ± 10.2 [b]		**9.4**
$MgCl_2$	33.2 ± 11.2 [d]	33.8 ± 8.1 [d]	33.2 ± 10.7 [d]	35.2 ± 10.8 [c]		**9.13**
$CaCl_2$	10.1 ± 4.8 [g]	16.3 ± 7.7 [g]	21.7 ± 6.2 [f]	28.8 ± 11.2 [e]		**7.4**
LSD 0.05	**8.2**	**7.4**	**11.1**	**10.0**		

This means that the rows and columns that have the same letter, are not significantly different at 0.05 level of probability.

2. The mean time (min.) for a honeybee is to consume 100 ml of mineral solution

Table (3) shows the time required to complete 100 ml of salt solutions of the elements. The time is inversely proportional to preference. The more time the bees consume the solution, the less the bees' preference. The less time the bees consume the solution, the greater the preference. This time was estimated in minutes. Honey bees prefer NaCl and its concentrations compared to tap water. Honeybees prefer diluted sodium chloride and its low concentrations. The solution was consumed at a concentration of 0.0125% after 139 minutes, a concentration of 0.025% after a time of 142.5 min., and a concentration of 0.05% after a time had passed 157.5 min. The longest time for bees to consume the solution was when the sodium chloride solution was concentrated at 0.1% was 163.5 min. The potassium chloride solution's consumption time at the concentration (0.1%) reached 171.0 min., and the minimum solution consumption time at the concentration (0.0125%) was 123.0 min. The same applies to calcium and magnesium solutions, where the lowest consumption time was for low concentrations and the highest consumption time was for high concentrations.

Table 3. The mean time (min) for honeybee is to consume 100 ml of mineral solution (%w/v)

Mineral solution	Mineral concentrations (w\v)				Tap water	LSD 0.05
	0.1	0.05	0.025	0.0125		
NaCl	163.5 ± 25.9 [b]	157.5 ± 19.0 [b]	142.5 ± 36.9 [d]	139.5 ± 22.4 [d]	199.8+48.1	**29.1**
KCl	171.0 ± 24.7 [b]	147.3 ± 23.1 [c]	138.0 ± 28.1 [d]	123.0 ± 24.3 [e]		**28.1**
$MgCl_2$	150.0 ± 23.5 [c]	156.0 ± 23.7 [b]	150.0 ± 18.7 [c]	142.5 ± 17.7 [d]		**25.8**
$CaCl_2$	190.5 ± 30.0 [a]	187.5 ± 32.6 [a]	175.5 ± 27.4 [b]	163.5 ± 29.5 [b]		**31.1**
LSD 0.05	**28.7**	**28.1**	**30.1**	**27.4**		

This means that the rows and columns that have the same letter, are not significantly different at 0.05 level of probability.

3. Visitation frequency ratios

Figure (1) shows the frequency of visits for different mineral solution concentrations by calculating the preference factor. The preference factor for NaCl solution was recorded at a concentration of (0.0125) Thus, the bees' preference for this concentration is higher than their preference for tap water. The lowest preference factor (0.4) was recorded with a $CaCl_2$ solution with a concentration of (0.1). In addition in Figure (2), low consumption ratios were recorded for 0.0125% potassium chloride (indicating a preference for the test solution), and higher consumption ratios were reported for 0.1% calcium chloride (indicating avoidance of the test solution).

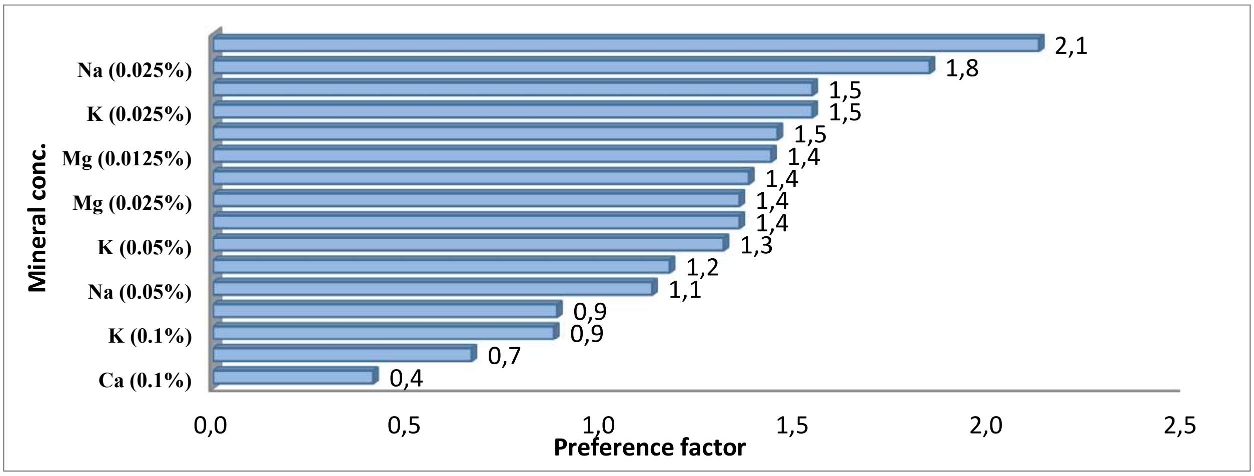

Figure 1. Visitation frequency ratios of different mineral solution concentrations.

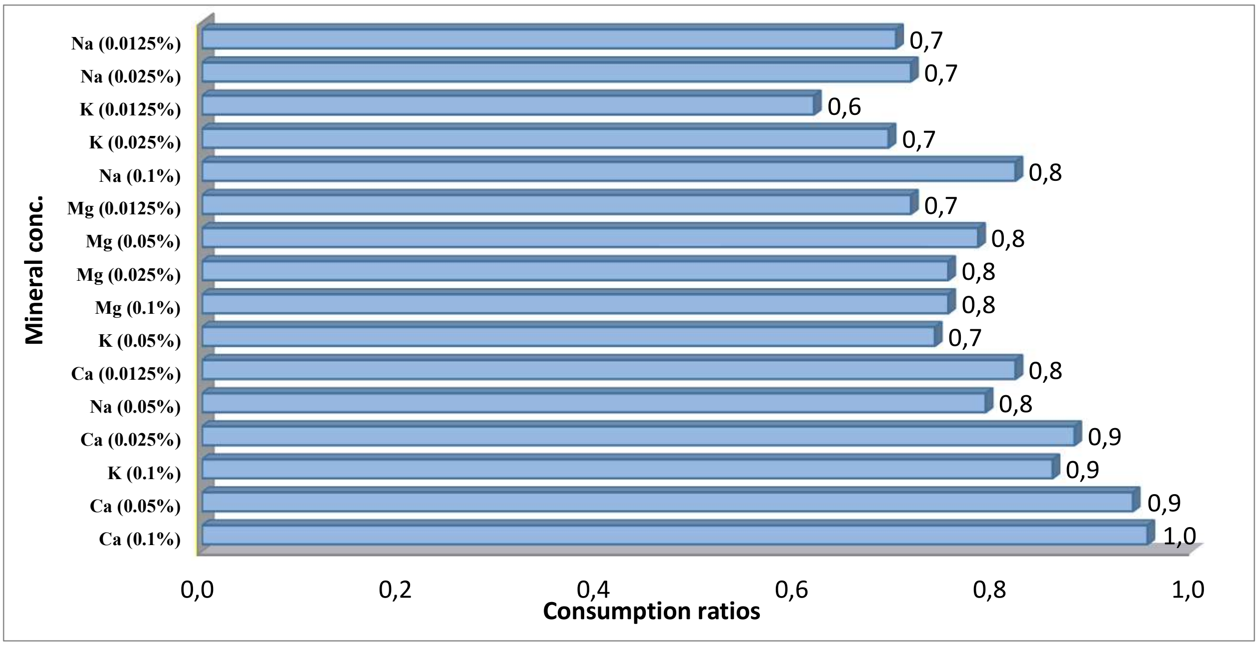

Figure 2. Consumption ratios for different mineral solution

DISCUSSION

The present study revealed that honey bees showed different micronutrient preferences. This confirms our theory that honey bees hunt for minerals lacking in their floral diet by foraging in contaminated water. Since these minerals are the most concentrated in honey bee products like honey, pollen, and royal jelly, four minerals in water solutions sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) were investigated. and because bees have a high need for these minerals additionally, sodium and potassium play important roles in the neurotransmission process in honeybees this finding is in line with the theories put forth by (Harrison 1987, Herrod-Hempsall 1931, Khan et al. 2021) mentioned that the instead of using the clean water source that is available in the apiary for their consumption, honeybees frequently collect water from a variety of undesirable sources, including runoff sewage, cow manure puddles, and gutters clogged with rotting organic debris. Therefore, it was crucial to identify what draws bees. Bees prefer salty water to pure water, according to experiments already done. Honey bees like to feed on minerals for their physiological activities and functions, such as muscular movement (Chakrabarti et al. 2020, Day et al. 1990, Wang et al. 2013), honey bees preferentially consume various minerals and salts. In the experiment with the single element at gradual concentrations, it was observed that it prefers low concentrations before gradually moving to higher concentrations. Different salts seemed to appeal to different types of bees. Thus, the type of salt had a significant impact. It was noted that calcium is weakly preferred in comparison to sodium, potassium, and magnesium. These findings support the findings of (Butler (1940) and, Cairns et al. (2021), and others who concluded that the bees preferred low concentrations of the element solution and did not favor it at higher concentrations when it was introduced at various concentrations. The findings support the assertions made by (Avarguès-Weber et al. 2015, Letzkus et al. 2006).Our results confirm earlier studies that found honey bees to have a preference for Na in "dirty water" (Bonoan et al., 2016), with the highest proboscis extension reflex (PER) to 1.5% NaCl solutions (Lau and Nieh 2016) and a preference for 0.29% NaCl over distilled water (Butler 1940). Similar findings were published by Lau and Nieh (2016), who found that forager bees strongly preferred a particular concentration of potassium, sodium, magnesium, and phosphate over deionized water.

Honey bee PER responses significantly decreased above 0.75% of this compound, according to Butler (1940), Lau and Nieh (2016), who reported very few honey bee visitations at 1.42% Na_2HPO_4. According to research by Bonoan et al. (2016 and 2018), foraging preferences for water solutions with 1% NaCl and $MgCl_2$ followed changes in pollen. Using tamed honeybees, Lau and Nieh (2016) found that the concentrations of NaCl, KCl, and $MgCl_2$ in water solutions ranged from 0.1% to 1.5%. Except for high Na, bees rejected high mineral concentrations in sucrose solutions; only high Fe and Cu concentrations caused an increase in total water intake when compared to the control. The fact that bees did not favor 1000 ppm of K diets over sucrose alone was also unexpected (De Sousa et al. 2022). Although honey bees have been observed to favor solutions containing 1500 ppm of K over sucrose alone, these authors eventually discovered that the acceptance-rejection concentrations of nectar minerals are species- and concentration-dependent for K (Afik et al. 2014). This corroborates earlier studies (Butler 1940, Lau and Nieh 2016) in which honey bees demonstrated aversions to K concentrations exceeding 1.5%. Similarly, Bonoan et al. (2018) discovered that honey bees avoided calcium during the summer and drank less of it than they did of Na.

Such as bees have found that the most effective way to obtain a balanced diet is to forage on multiple resources simultaneously. Over several hours of our observation, bees were noticed when experimental solutions were placed, hovering around all the solutions and taking approximately 20 minutes to determine the preferred solution. When this solution ended, we thought it would take some time to reassess the other solutions, but when this solution ended, the next preferred solution was already approaching it. This indicates that the initial time (20 minutes) was spent evaluating all the solutions, organizing them to be preferred, and memorizing them for bees. The significance of micronutrients like calcium, magnesium, and sodium in honeybee diets has not received much attention from studies (Black 2006, Brodschneider & Crailsheim 2010), the micronutrient needs of honeybees vary depending on the season. Most observers typically attribute honeybees' preference for drinking water to the amount of salt present. However, there are at least four key components that are likely to be significant: sight, (Chakrabarti et al. 2020, Jaleel et al. 2020) description of the sense of water perception, the perception of numerous odor chemicals present in the water, and the sense of taste after being submerged. The honeybee prefers to consume the water in the time afternoon because of the high temperature in the summer season, the time it takes for one flight to collect water is significant, as the bee spends a minute or more taking the load of water and spends one minute flying a distance. Honeybees do not typically collect a lot of water in the morning, and the majority of the water sources are consumed at noon (Bänziger et al. 2009, Nawaz et al. 2020).

The water-collecting bee travels 400 meters, spends 2 to 3 minutes inside the hive, and makes 100 visits. It is crucial to understand the nutrient and mineral requirements of bees because this knowledge will help in the creation of a synthetic diet for honeybees. According to the needs of the honeybee colonies, enhances the colony's health and could improve beekeeping and assist in developing a full diet for honeybees (Khan et al. 2021).

Conclusion: The results showed that honey bees have a strong preference for salt solution compared to tap water depending on the type and concentration of the element. This study has implications in applied and basic sciences for understanding the mineral-selective behavior of honey bees and determining the appropriate and preferred concentrations of the mineral solution Na, K, Mg, and Ca, and they can self-select minerals based on concentration; they can control the intake of low concentrations and avoid high concentrations. Overall, collecting information about the minerals preferred by honey bees can help us better understand the nutritional ecology and overall health of honey bees.

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