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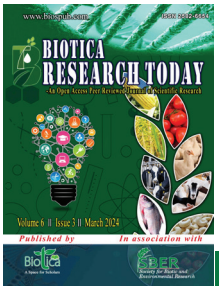

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Buzzing Repercussions: Busy Bees Require Sleep as Well

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Abstract

In recent neurobehavioral research demonstrated that resting behavior in bees shares several common characteristics with sleep in vertebrates. As honeybees are the social insects, which perform the activities such as nest cleaning, foraging, pollination and waggle dance. To carry out these activities productively, they must have adequate sleep. However, some factors may cause disturbance in sleep which leads to sleep deprivation. Due of sleep deprivation, they may be less accurate in their waggle dances while directing others to food sources. The efficiency with which nestmates can forage and other ecological services would likely decline as honey bee communication declines, which could ultimately result in colony failure and decreased crop yield. This article explains bees sleep pattern, factors causing sleep deprivation and its consequences which can direct efforts to promote agricultural methods that are safe for honey bees, protecting these vital pollinators in agricultural system.

Keywords: Circadian clock, Honeybee, Memory consolidation, Sleep deprivation

Introduction

Honeybee pollination is vital for agriculture, serving as a cornerstone for crop production. The mutualistic relationship between plants and honeybees, facilitated through nectar and pollen exchange, significantly enhances crop quality and quantity globally. *Apis mellifera* L. (Western honey bee) is the predominant pollinator, fulfilling 34% of the United Kingdom's pollination service demands. While other bee species contribute, research has primarily focused on limited types, such as bumble bees (*Bombus* spp.). Notably, the USA recognizes honey bees' pivotal role, resulting in a 10% yield increase in cucumber crops. India has also leveraged honey bee pollination, demonstrating improved guava fruit quality and enhanced dimensions for coconut and citrus fruits compared to controls. This underscores the economic and dietary benefits of honeybee pollination on a global scale.

Beyond their essential role in pollination, honey bees engage in diverse activities crucial for hive functioning. These encompass nest cleaning, foraging missions; where bees collect pollen and nectar and the intricate waggle dance. This dance is a communication tool, conveying information about desirable foraging and nest locations. The dance's duration indicates distance, while the angle relative to the sun's azimuth signifies direction. Honey bees exhibit constant activity throughout the day while sleeping in the night, with some species even taking short naps between tasks. However, their nocturnal sleep can be disrupted by various factors, such as nighttime warming, noise, vibrations, artificial light, exposure to chemicals and ecological interactions. Disrupted sleep, may adversely affect honey bees' circadian rhythm, foraging, navigation, waggle dance signaling and reproductive success (Khalifa *et al.*, 2021).

Honey Bee Sleep

There is growing evidence to support the theory that insect resting states are similar to human and other vertebrate sleep. According to groundbreaking studies on bees, both at the neurological and behavioral levels, honeybee resting phases share several characteristics with vertebrate sleep. These shared traits include (i) prolonged periods of inactivity; (ii) rapid reversibility of the inactive behavioral state; (iii) higher thresholds for arousal; (iv) particular resting postures; and (v) the presence of homeostasis, which is demonstrated by a "sleep rebound" after periods of sleep deprivation.

The role they play in the colony affects how honey bees sleep. Due to the impracticality of foraging in the dark,

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forager bees follow a day-night cycle similar to that of humans. Throughout a 24-hour day, however, young honey bees display a more variable sleep cycle (Figure 1). Their function in the colony is reflected in their sleeping site selection, which is not random. While experienced foragers choose locations along the hive's edge, younger bees prefer to sleep closer to the middle of the nest, frequently inside honeycomb cells. When scouts are searching for new colony locations, they might sleep somewhere else than the hive, maybe taking a quick nap at a possible location before the swarm arrives. The drones of honey bees may decide to rest on a comfortable plant, distanced from the hive, queen bees find comfort in sleeping within their hives.

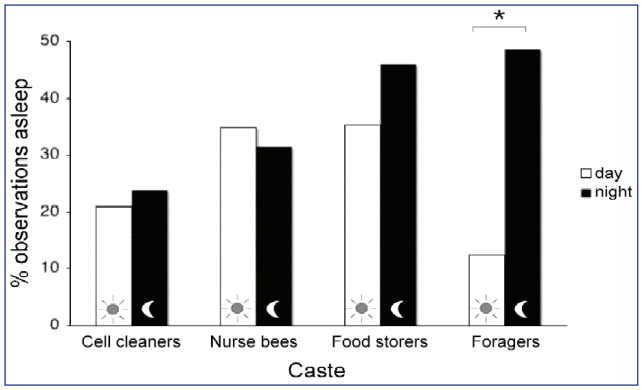

Figure 1: Cast based sleep pattern in honeybee

Because *Apis mellifera* has decreased performance in daily jobs when its sleep schedule is disrupted, bees are obligated to sleep throughout the night. Even simple things like finding a new route home will become difficult. Waggled dances are difficult for honey bees to perform when they are sleep-deprived. Research revealed that bees that were sleep-deprived had trouble communicating and performed their waggle dance less accurately. Inadequate sleep patterns also have an impact on a bee's memory. Orientation flights take longer, and they have trouble finding familiar food sources (Kaiser and Steiner-Kaiser, 1983).

Factors Causing Insect Sleep Disruption in Bees

1. Night Warming

Temperatures at night have increased faster than those during the day during the past 50 years due to changes in the climate. Thus, not enough attention has been paid to the effects of this asymmetry on small, free-living, diurnal ectotherms (like honey bees), whose fitness-related traits and nighttime sleep may be vulnerable to heat exposure. The photoperiod and thermoperiod may become desynchronized as a result of warm nights having an impact on the core oscillator that controls daily activity patterns. In contrast, because of altered time perception, bees might experience a reset to their internal clock (Tougeron and Abram, 2017).

2. Noise and Vibrations

The numerous impacts of man-made noise on honey bees, such as changes in their foraging habits and ability to reproduce, are becoming more and more evident. Though research in lab settings has extensively investigated the direct effects of noise-induced sleep disruption on insects, there is evidence that these disturbances may also affect their mechanosensory systems, depending on the taxon, through either receptivity to far-field sound or substrate-borne vibrations. Moreover, unfavorable meteorological elements like wind and rain may mimic vibrations by forcing honey bees from their sleeping spots and mechanically upsetting their sleep cycles.

3. Night Light

For diurnal creatures, artificial lighting at night can be a major source of stress since it influences various elements of their behavior, such as sleep patterns, and because light serves as both a resource and an information source (Tougeron and Abram, 2017).

4. Exposure to Agrochemicals

Bees come into contact with synthetic chemicals in the wild, especially in agro-ecosystems where pesticides and other chemicals are frequently utilized and leave behind lingering residues. Tougeron and Abram (2017) claimed that substances present in ecosystems may operate on specific brain receptors and the endocrine system, that are involved in daily cycles and sleep expression, and so have the potential to cause sleep deprivation or limitation.

5. Ecological Interactions

Honey bee sleep disturbances can result from various ecological interactions, including social interactions, parasitism, competition and predation. Species active at different period of the day have adapted to prevent temporal niche overlap, which may affect each other's sleep patterns. Accordingly, through direct unintentional physical disruptions, the feeding habits of one species may cause sleep disorders in another (Tougeron and Abram, 2017).

Potential Consequences of Sleep Deprivation

A recent study focused on the detrimental impact of neonicotinoid ingestion on bee's circadian rhythms, particularly exacerbated under light exposure. This disruption of behavioral patterns exhibits a dose-dependent correlation during light periods or constant light. In contrast, the impact on circadian rhythms is notably minimized without light cycles. Neonicotinoids not only modify the rhythmic behavior of bees but also prolong their rhythm post-ingestion, resulting in delayed activity offset and extended nocturnal activity.

Given that crucial honey bee activities such as foraging, navigation, and learning/ memory processes are intricately linked to circadian clocks, the implications are profound. Neonicotinoids may specifically target clock neurons in honey bees, disrupting navigation in foragers and impeding learning and memory processes. The honey bee's circadian clock is linked to these disturbances, even though the exact mechanisms causing them are yet unknown. A clock-regulated process, sleep plays a critical role in facilitating social communication and the consolidation of navigational memory, most notably in the waggle dance used by foragers to transmit the whereabouts of food sources.

Effect on Navigation Memory Consolidation

Honeybees engage in the systematic collection of nectar from specific locations until the resource is depleted. Returning to the hive after visiting a particular plant requires the ability

to remember visual landmarks in the hive environment. The navigation learning process for honeybees is gradual. The first thing that juvenile foragers do is take off on exploratory orientation flights to become acquainted with the local solar azimuth-time function, the look of the hive entrance, and the spatial relationships between nearby landmarks. Afterward, foragers use waggle dances to communicate directions and distances as they figure out the best paths between food locations and the hive. Learning a new flight path requires adding fresh experiences to the navigational memory that already exists. Memory consolidation in bees is probably influenced by sleep. Sleep deprivation is expected to impair memory consolidation and reduce the effectiveness of foraging bee-homing flights. According to Beyaert *et al.* (2012), it is noteworthy that 42% of the bees were lost during the first homing flight and 17% during the second.

Effect on Waggle Dance Signaling

The waggle dance, a distinctive figure-eight movement performed by honey bees, serves as a crucial communication method among foragers. This dance communicates the direction and distance to various resources like nectar-rich flowers, pollen, water sources, or potential nest sites to the colony members. According to Klein *et al.* (2010), the round dance in *Apis mellifera ligustica* changes into transitional dances and then becomes the waggle dance for resources that are farther away from the hive than 40 meters. In a laboratory study involving sleep deprivation through an inseminator device, it was observed that sleep-deprived honey bees exhibited diminished effectiveness in waggle dance signaling. These sleep-deprived bees experienced the degraded transfer of directional information through their waggle dances, leading to miscommunication of the direction to food sites among colony members. This communication breakdown can result in less efficient foraging, decreased pollination and the potential loss of colony members, ultimately posing a threat to the overall survival of the bee colony (Klein *et al.*, 2010).

Conclusion

Sleep in honeybees is considered as an important biological phenomenon that regulates its behaviour. These creatures precisely choose designated sleeping location and adopt specific sleep postures. However, diverse environmental factors cause disruption in honeybee sleep. These disturbances in sleep extend to impactful consequences on their daily activities, from foraging and navigation to time-memory related to food sources as well as learning and memory processes. Sleep deprivation could potentially contribute to the collapse of bee colonies, raising significant concerns for agriculture, which is heavily reliant on bees for pollination services. Recognizing the vital role of bees in agriculture emphasized the need to protect bees from environmental factors inducing sleep deprivation. The adoption of Good Agricultural Practices (GAP) will be the better solution for ensuring the well-being and sustained productivity of these vital pollinators.

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