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RESEARCH ARTICLE

Effect of some climatic variables on the amount of pollen during the winter season of *Apis Mellifera* L.

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Abstract

Honey bees (*Apis mellifera* L.) play a critical role in global agriculture and biodiversity due to their pollination services and production of economically valuable hive products such as pollen. However, winter conditions, including low temperatures and high humidity pose significant challenges to colony productivity. The objective of this study was to investigate the impact of controlled hive microclimates on pollen production during winter 2023. Six Langstroth hives were divided into two groups: three treated hives covered with black polyethylene to enhance internal warmth; and three control hives under standard conditions. Pollen stores, internal temperatures, and humidity levels were recorded every 13 days. Treated hives exhibited significantly higher mean pollen production (64.00 cm², SD = 32.46) compared to control hives (51.00 cm², SD = 30.05; $p < 0.05$). Internal temperature (b = 6.810, $p = 0.005$) and humidity (b = 0.465, $p = 0.001$) positively correlated with pollen production in treated hives, while these effects were negligible in controls. The results indicated that microclimate adjustments significantly improved winter colony productivity. Beekeepers are recommended to adopt simple modifications, such as hive insulation and supplemental feeding, to enhance colony resilience and productivity in challenging climates. Further research on additional environmental factors is essential for optimizing hive management strategies.

Keywords: *Apis mellifera* L; honey bees; pollen; humidity; temperature

1. Introduction

Honey bees (*Apis mellifera* L.) are indispensable contributors to global agriculture and biodiversity, serving as the primary pollinators for approximately 75% of flowering plants and 35% of global food crops (Brosi *et al.*, 2017; Villagomez *et al.*, 2021). The ecological and economic significance of honey bees is profound, with their pollination services estimated to be worth \$170–\$200 billion annually (Norrström *et al.*, 2021). In addition to their pollination role, honey bees produce economically valuable products such as honey, wax, royal jelly, and pollen. Pollen, often referred to as "bee bread," is particularly important due to its role in supporting larval development within hives and its use as a dietary supplement for humans (Branchiccela *et al.*, 2021). However, the productivity and health of honey bee colonies are increasingly threatened by environmental stressors, including climate change, habitat loss, and agricultural intensification (Ma *et al.*, 2019).

Among environmental factors, temperature and humidity are critical determinants of honey bee behavior, productivity, and survival. Temperature significantly influences metabolic activity, foraging patterns, and brood development in bee colonies. For example, foraging activity peaks at temperatures between 20°C and 30°C, while extreme temperatures can inhibit flight and reduce pollen and nectar collection (Tan *et al.*, 2012; Prabucki *et al.*,

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1985). Similarly, humidity within the hive plays a vital role in regulating nectar dehydration, pollen preservation, and honey production (Erdogan *et al.*, 2019). Elevated humidity levels are associated with improved nectar-to-honey conversion rates and colony hydration. Conversely, deviations from optimal temperature and humidity levels disrupt hive homeostasis, impair colony health, and reduce productivity (Mitchell, 2019; Smith *et al*., 2018). Winter season presents significant challenges to honey bee colonies, as low temperatures and limited floral resources amplify the impact of environmental stressors (Norrström *et al*., 2021). Previous study reported that winter survival depends heavily on stable internal hive conditions (Scott *et al*., 2023). In colder climates, colonies often experience substantial weight loss due to increased metabolic demands for thermoregulation (Camargo *et al*., 2018). Furthermore, climate change-driven alterations, such as warmer winters and shifts in floral phenology, exacerbate these challenges by creating mismatches between flowering periods and foraging activities (Villagomez *et al*., 2021). These disruptions underscore the vulnerability of honey bees to environmental variability and the urgent need for adaptive management strategies.

Recent research emphasizes the potential of controlled environmental modifications to mitigate the adverse effects of climate changes on honey bee colonies "need references here". For instance, insulated hives and regulated humidity levels have been shown to enhance colony productivity during winter, improving honey and pollen yields (Erdogan *et al*., 2019; Branchiccela *et al*., 2023). Nutritional supplementation, such as providing protein-rich pollen substitutes, has also been found to support colony strength during resource-scarce periods (Branchiccela *et al*., 2021). Despite these advancements, the specific impact of environmental modifications on winter pollen production remains underexplored, creating a gap in current knowledge.

The objectives of this study were to investigate the effect of controlled environmental modifications on pollen production in *A. mellifera* colonies during the winter season. By examining the relationship between temperature, humidity, and pollen yields, the research aims to provide insights into optimizing hive management practices for increased productivity. The findings are expected to contribute to sustainable beekeeping practices and enhance colony resilience in the face of climate change.

2. Materials and methods

2.1. Area of Study

The study was conducted at the South Valley University research farm, located in Qena, Egypt. This region experiences a cold winter climate with significant seasonal variations in relative humidity. The research farm is surrounded by a mix of cultivated crops and natural vegetation.

2.2. Hives Preparation

During the winter season 2023, Six standard Langstroth hives were used for this study. These hives, made of wood and equipped with ventilation controls, were standardized in size and population. Queens of the same age headed all colonies to ensure uniformity. The hives were placed in a single row, with a 5-meter minimum spacing between hives to reduce drifting. The orientation faced southeast to maximize exposure to early morning sunlight and minimize strong afternoon winds.

2.3. Treatments

The experiment utilized two groups of hives:

1- Control Group: Three hives (Hives 4–6) were left under normal apiary conditions without modification.

2- Treated Group: Three hives (Hives 1–3) were covered with black polyethylene bags to absorb sunlight and enhance internal hive warmth.

Protein supplementation was provided in the form of protein dough (honey, powdered sugar, and pollen grains) for all hives to compensate and reduce natural pollen availability and stimulate egg-laying.

2.4. Data Records, Parameters, and Observations

Data were collected every 13 days during the winter of 2023, focusing on**:** Pollen Stores: Measurements in square centimeters (cm²) were recorded for each side of each hive frame. Internal Hive Temperature and Humidity was measured using digital devices to capture both internal and external environmental conditions. Climatic Parameters**,** including daily temperature and relative humidity, were monitored to correlate with pollen collection and hive productivity.

2.5. Data Analysis

All statistical analyses were performed using SPSS software, version 24 (IBM Corp., 2024). The following methods were employed: Correlation Analysis, to examine relationships between climatic factors (temperature and humidity) and hive parameters such as pollen stores. T-tests was used to compare the means between treated and controlled groups. Multiple Linear Regression was used to identify the influence of temperature and humidity on pollen production. Statistical significance was determined at a 0.05 probability level. The results were graphically represented to illustrate trends in pollen production and environmental conditions.

3. Results

The impact of controlled hive treatments on pollen production, internal temperature, and humidity was assessed during the winter season of 2023. The findings are summarized in Tables 1, 2 and 3, and the trends in pollen production are illustrated in Figure 1.

Table 1. Climate Variables Recorded inside and outside Treated Hives During Winter 2023

Hives	Variables	R	B	S.E	P-value
Treatment	Temperature, inside	0.790	6.810	0.013	0.005
	Temperature, outside	0.590	7.351	0.018	0.054
	Relative humidity, outside	0.890	0.465	0.011	0.001
Control	Temperature, inside	0.206	-11.984	11.216	0.981
	Temperature, outside	0.376	-2.669	13.342	0.854
	Relative humidity, outside	0.802	4.869	19.966	0.133

Table 2. Climate Variables Recorded in Control Hives During Winter 2023.

Variables	Measuring unit	Mean± S.D.	Max.	Min.
Pollen amount	Cm²	64.00±32.46	109.00	0.00
Temperature, inside	°c	30.49±2.16	34.50	27.25
Temperature, outside	°c	28.82±1.91	33.00	26.00
Relative humidity, outside	%	36.71±0.755	38.00	36.00

Table 3. Correlation Analysis of Climate Variables and Pollen Production inside and outside Treated and Control Hives

Variables	Measuring unit	Mean± S.D.	Max.	Min.
Pollen amount	Cm²	51.00±30.05	88.76	0.00
Temperature, inside	°c	29.00±1.15	33.50	26.32
,Temperature, outside	°c	28.82±1.91	33.00	26.00
Relative humidity, outside	%	35.65±0.84	38.50	37.61

3.1. Pollen Storage

The treated hives exhibited a mean pollen area of 64.00 cm² (SD = 32.46), with production ranging from 0.00 to 109.00 cm². In contrast, the control hives showed a lower mean pollen area of 51.00 cm² (SD = 30.05), with a range of 0.00 to 88.76 cm² (Table 1 and 2). Internal and External Temperature

The mean value of internal temperature was higher for treated hives (30.49°C; SD = 2.16) as compared with control hives (29.00°C; SD = 1.15).). External temperatures were consistent between the groups, averaging (28.82°C; SD = 1.91).

Relative humidity was slightly higher in treated hives (36.71%) compared to control hives (35.65%; SD = 0.84). This small difference, however, demonstrated a significant effect on pollen production as shown by regression analysis (Table 3). For treated hives, humidity exhibited a positive correlation (b = 0.465, p = 0.001), emphasizing its critical role in enhancing pollen storage efficiency.

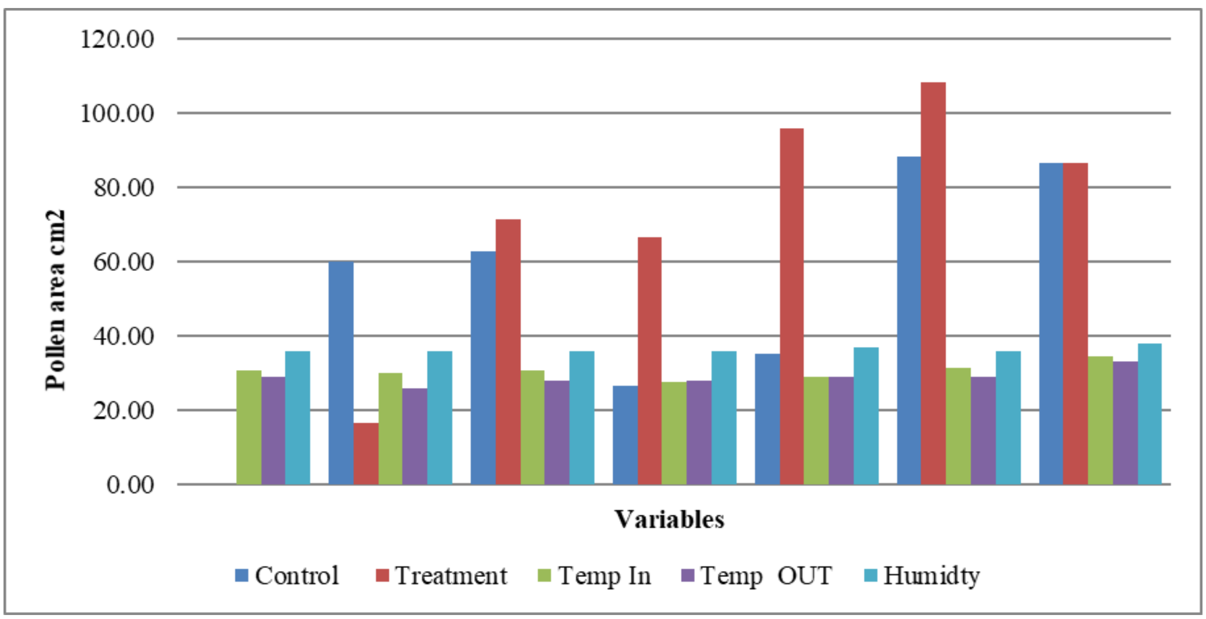

Figure 1. Comparative Trends in Pollen Production Between Treated and Control Hives During Winter 2023.

Regression models revealed that internal temperature and humidity influenced pollen production in treated hives, with internal temperature showing the strongest effect (b =

6.810, $p = 0.005$). Conversely, these factors had minimal impact in control hives, as shown by the non-significant coefficients for internal temperature ($b = -11.984$, $p = 0.981$) and humidity ($b = 4.869$, $p = 0.133$).

4. Discussion

The results of this study demonstrate that controlled hive modifications, such as the use of black polyethylene coverings, positively impact pollen production during the winter season. These findings align with prior research highlighting the influence of internal hive microclimates on colony performance (El-Sheikh *et al.*, 2021). Optimizing the hive environment plays a critical role in enhancing productivity during challenging climatic conditions.

The significant increase in pollen production observed in treated hives aligns with earlier studies indicating that optimal temperatures (20–30°C) enhance worker activity and pollen foraging efficiency (Tan *et al.*, 2012; Prabucki *et al.*, 1985). Treated hives in our study maintained internal temperatures closer to this optimal range, thereby promoting pollen collection and storage. Erdogan (2019) also demonstrated that insulated hives improved colony performance by maintaining stable temperatures during adverse conditions, underscoring the practical value of hive insulation in improving productivity (Erdogan, 2019).

Humidity, another critical factor, was also shown to influence pollen production positively. Our results revealed a strong positive correlation between hive humidity and pollen production ($b = 0.465$, $p = 0.001$). Elevated humidity levels likely facilitated pollen processing and storage. Similar conclusions were drawn by Erdogan (2019), who reported that optimal humidity enhances nectar dehydration and pollen preservation (Erdogan, 2019). Control hives, which experienced slightly lower humidity levels, demonstrated reduced pollen yields, emphasizing the importance of maintaining balanced humidity to optimize productivity (Mitchell, 2019). The combined effects of increased temperature and humidity in treated hives created a microclimate conducive to enhanced worker activity, egg-laying, and pollen storage. This finding echoes Norrström *et al.* (2021), who noted that stable internal hive conditions reduce colony stress and improve resource utilization during the winter (Norrström *et al.*, 2021).

Additionally, the provision of protein supplements likely supported colony health and productivity. As reported by Branchiccela *et al.* (2023), supplemental feeding mitigates nutritional stress and promotes foraging efficiency, a strategy that could be particularly beneficial in resource-scarce winter conditions (Branchiccela *et al.*, 2023). The integration of warming systems has also been shown to significantly enhance productivity. Studies such as those by El-Sheikh *et al.* (2021) and Oskin *et al.* (2020) demonstrated that maintaining stable hive temperatures, particularly using controlled systems, can dramatically improve pollen yields and overall colony strength.

5. Conclusion

This study demonstrates the efficacy of controlled hive modifications in enhancing pollen production during winter season. The results emphasize the critical role of internal hive conditions, particularly temperature and humidity, in optimizing colony performance. These findings provide actionable insights for improving beekeeping practices, particularly in regions with challenging climatic conditions. By adopting simple and cost-effective strategies, beekeepers can enhance productivity and resilience, ensuring the sustainability of their operations.

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Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors of the manuscript have read and agreed to the publication, all authors have agreed to the submission to the journal

Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no conflicts of interest.

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Authors' contributions

GSM supervised the work, reviewed, and edited the manuscript for critical revisions and provided guidance throughout the research process. MAA designed the study, provided, drafted the manuscript and assisted with data analysis and interpretation. DRM data collection, and conducted experiments. All authors read and approved the final manuscript.

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